SUSTAINABLE MANAGEMENT OF RIVER FLOWS AND WATER EXTRACTIONS IN VIET NAM:

A REVIEW OF INTERNATIONAL APPROACHES TO DETERMINING APPROPRIATE MANAGEMENT RULES.

REPORT 1

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1. Purpose of this report

Like most developing countries in Asia and elsewhere, the Government of Viet Nam has been driven by the need for rapid economic development and urbanisation aimed at improving the quality of life for its people and at poverty reduction. This requires the development of major new water supply systems and increases in the use of water for a wide range of purposes.

Unfortunately, there has been little consideration of the impacts of changes in flow regimes and extraction of water on natural river or aquifer processes with the result that river health suffers and aquifer levels decline. Not only does this affect the environment but it also has consequences for the use of the river for a variety of basic human use purposes (household water supply, fishing etc) and for the long-term viability of economic development.

The potential impacts of water use development on the long-term health of water sources is recognised, at least in a general policy sense, by the government in Viet Nam. Unfortunately there are no established procedures or methodologies in Viet Nam for determining appropriate management rules or for providing consistent and useful information to those making development and water use decisions about potential impacts and how to mitigate them. It is also evident that there is no widespread appreciation of the links between disruption of flow regimes and extraction of water and declines in water quality, and production of fish and other valuable natural products and services which rivers provide.

Viet Nam is soon to embark on a river basin planning process. It is important that procedures and methodologies are developed and adopted before this process gets underway. Without them there will be inadequate consideration of potential long-term damage to water sources and the consequent economic and social costs to the country and future generations. Decisions will continue to be based on more readily perceived immediate economic development benefits.

Considerable effort has been made in many countries to develop procedures and methodologies. Those that have been developed range from very simple single focus methods to quite complex frameworks which encompass social and economic considerations as well as potential impacts on long-term water source health and productivity.

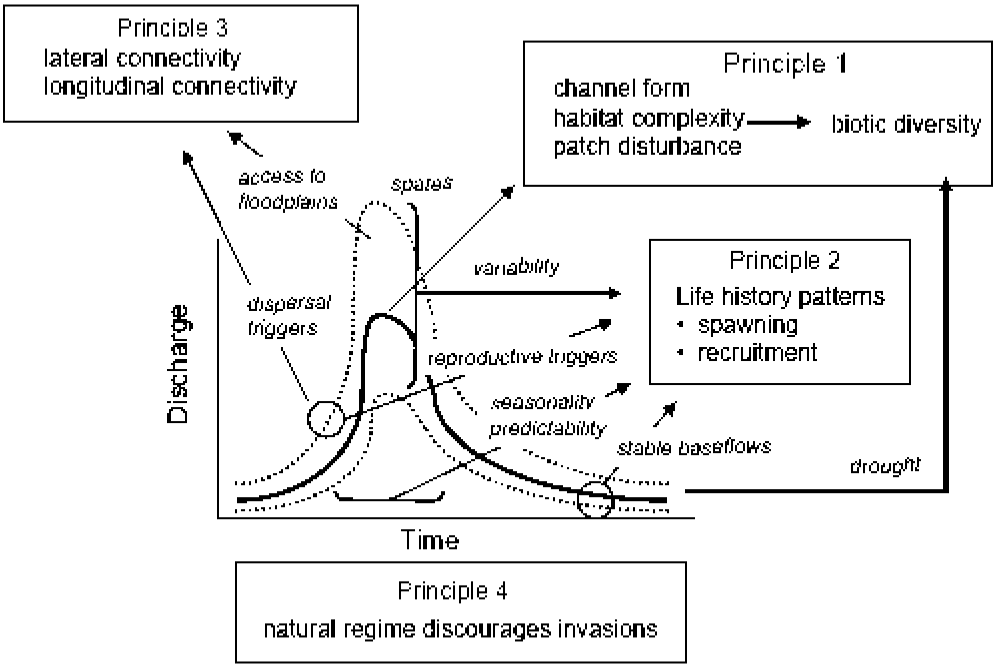
The purpose of this first report is to assess existing international methodologies and see whether any could be appropriate for adoption in Viet Nam. This first report will be followed by two further reports. The second report will assess the short listed approaches in more detail and then propose a methodology for adoption in Viet Nam. The final report will refer to the considerations and conclusions of this report, and those of the second report but do so in as concise and readily digestible fashion as possible.

The process for developing a methodology for Viet Nam will also include two workshops and an overseas study tour. The first workshop will occur before preparation of the second report. It will be aimed at disseminating information about overseas practices and reaching agreement on the most appropriate models to examine as part of the study tour. The second workshop will occur after the study tour and before finalisation of the final report. It will be aimed at informing decision makers and other relevant parties about the proposed methodology for Viet Nam and will seek their comments for incorporation into the final report.

2. Surface Water Background

2.1 THE CONNECTION BETWEEN WATER USE DEVELOPMENT, RIVER FLOWS AND RIVER HEALTH

The following diagram, (Bunn and Arthington 2002) shows some of the connections between a river's natural flow regime and the resulting plant and animal responses and geomorphic processes.



The 'principles' which the diagram refers to are that:

1. major flow events drive geomorphic processes, determine the form of habitat available for plants and animals and therefore set limits to those that can continue to exist in a river system,
2. the plants and animals associated with a river have evolved responses that match the opportunities and pressures provided by the natural flow
3. many animal species in rivers, and plant and animal species adjacent to rivers, require the periodic connections that occur during floods if they are to survive, disperse and prosper, and
4. that changes to the flow regime reducing the competitive advantage of endemic species and encourage colonisation by exotic and introduced species – and possibly also dominance of a sub set of the existing range of species.

As the diagram shows, these links exist at all flow levels and at all temporal scales. Because of this any change to the natural flow regime as a result of dam construction and regulation of river flows or extraction of water will have some impact on plant and animal responses and/or river processes.

Generally changes to the flow regime will have negative effects on the numbers of naturally occurring plants and animals and, if the changes are excessive, may even result in their total loss from a river. This is because the flow changes disrupt breeding cycles, contribute to reduced water quality, lead to loss of habitat and may favour introduced species of plants and animals. They will also often produce adverse geomorphic impacts which add further to impacts on plants and animal numbers and established community uses of the river.

Dams are constructed on rivers to allow "time shifting" of the flow of water from the catchment upstream of the dam into the river downstream of the dam. This results in a flow regime downstream of the dam which, when compared to the natural flow regime, will generally show changes in:

- short term variability – flows may be more or less variable;
- seasonality – flows may be moved from a wet time of the year to a dry time,
- inter-year variability – with flows moved from years of high flow to years of low flow

The purpose for which water is used in a regulated river system is also important with respect to impacts on the scale and timing of impact on flows. With respect to their general effect on the flow regime the purposes can be placed in the following general usage categories:

- agricultural,
- riparian household supply/ urban supply
- hydro-electricity.

Agricultural water demands are seasonally variable and inversely related to rainfall. Therefore the total taken may vary substantially from year to year even though there has been no change in the underlying average demand. Riparian household and urban supply demands are relatively constant throughout the year and are relatively little affected by year to year or even seasonal variations in climate. Hydro-electric demands vary with demand for power. This is generally not significantly related to rainfall or to time of the year. However, great variations in releases may occur over very short time frames in response to changes in demand for power during a day, and in particular from peak to off peak periods of the day.

In an unregulated river the only impact on the flow regime comes from the extraction of water. Because there is no "time shifting" of inflows, the only effect that can occur is a loss of flow volume. Because the diversion capacity of extraction works is generally small relative to floods and even "normal" flows, and because agricultural extractions are generally higher during times of low rainfall, the loss of flows is generally most pronounced during low flow times. The relative effect of extractions at such times may however be quite large and persist for long periods. As a result, the consequences to river health can be serious.

What is "river health"?

"River health" has been given a variety of definitions in the scientific literature and there are a number of indices being used in various countries to assess the health of rivers. Often these definitions and indices use a river's natural state as the condition that defines good river health. Such a definition is however not reasonable in Viet Nam where the preservation of "natural" conditions is generally a much less realistic goal here than in many western countries, particularly as many river systems and their ecosystems have been affected by human uses for a very long period.

Therefore, for the purposes of this report, river health is assumed to refer to a river's ability to maintain key physical, chemical and ecological processes and a community of organisms with a desired species composition, diversity, and population despite any natural or man made disturbances that can be reasonably expected. The processes and organisms that indicate good health may be those that were there naturally or may be some altered assemblage that the community accepts as reasonable in the light of the long-term benefits it wishes to derive from the river. Any change from "natural" that is used to define good health should not however be one which substantially or unjustifiably limits future generations choices in relation to use of the river.

2.2 RIVER FLOWS AND WATER USE IMPACTS IN VIET NAM

2.2.1 Flow distribution and the impacts of current water exploitation.

A simple comparison of the total flows in Viet Nam's rivers with water extractions would lead to the conclusion that there should currently be minimal conflict between development and water extractions and maintenance of river health. The total average annual volume of flow in rivers entering the sea along Viet Nam's coast is approximately 835 billion cubic metres. Water use however is only around 90 billion cubic metres per annum, of just 11% of the total average outflow. A simple comparison of average flow with usage is however likely to be misleading, because much of the flow of any river comes during flood times, and is not really available at a times when most water use occurs. However, even taking this into account, as the World Meteorological Organisation (WMO 1997) has done in their water stress index (see table 1 below), this simple comparison would seem to indicate there should not currently be too great a problem.

TABLE 1 –WATER SCARCITY INDEX
World Meteorological Organisation

Water stress is defined as a country's estimated volume of water used per annum expressed as a percentage of the estimated available water resource. Four levels of stress are identified:

(1) Low water stress —Where less than 10 per cent of their available water resource is used there is generally little pressures on water resources.

(2) Moderate water stress — Where the use of water is estimated to be in the range 10 to 20 per cent of the available resource, water is becoming a factor which is limiting development. Efforts are needed to reduce demand and investments are required to increase supplies.

(3) Medium to high water stress — Here water use is in the range of 20 to 40 per cent and careful management is needed to ensure that uses remain sustainable. Competition between different human uses has to be resolved and attention given to ensure that there are flows adequate for aquatic ecosystems.

(4) High water stress — Use of more than 40 per cent of the available resource indicates a position of scarcity and often the use of water at a rate faster than the natural replenishment. Alternative sources such as desalination have to be developed, and urgent attention must be given to the intensive management of the resource and the demands made on it. Present patterns of use are not likely to be sustainable and scarcity of water is becoming a limiting factor to economic growth.

This simple indicator is however misleading when applied to Viet Nam for four main reasons.

The first is the uneven geographic spread of Viet Nam's surface water. Around 60% of the total volume comes via the Mekong (Cuu Long). However, the Mekong delta region of Viet Nam makes up just 12% of the country and accounts for only and 20% of the population and about 30% of water use. If the country is examined on a regional basis, then the figures are much less comforting. In the region with the highest proportional water use, the coastal area between Da Nang and Nha Trang, 35% of total flows are being consumed. In the region between Thanh Hoa and Hue water use is 23% of total flow (World Bank 2003). Therefore, over approximately 25% of the country, water use is already occurring at a rate that the WMO would consider unsustainable without careful management. The uneven spread of water resources is also apparent from water per capita figures. In the Mekong delta there is 28,000 cubic metres of water on average per person, however in the Dong Nai Basin there is just 3000 cubic metres per person.

The second reason is the uneven spread of runoff over the year. Typically, the average runoff in the driest 6 months, the time of highest water demand, is only between 15% and 30% of total annual runoff. Of the 9 major river basins in the country 6 frequently have major water shortage problems during the dry season (ONWRC 2003). This clearly indicates that a very high proportion of flows is being taken from many of Viet Nam's rivers at low flow times. The ONWRC report goes on to say that in many areas the total dry season demand is already frequently higher than the available supply. This situation will only worsen with time. The report estimated that by 2010 dry season demands will have increased from 70.7 x 109 cubic metres to 90.2 x 109 cubic metres.

The third reason is that the flows in many Viet Nam's rivers are also disrupted by storage and release of water for hydro-electric power. Hydro power accounts for 55% of the country's total power production capacity (World Bank 2003)

The fourth reason is that water development and water use in upstream countries is also affecting the two main rivers which flow through Viet Nam, the Mekong and the Red River (Song Hong).

If these factors are taken into account it is clear that water exploitation in many of Viet Nam's rivers is already at levels that experience in other countries demonstrates will contribute significantly to water quality problems, declines in natural aquatic food stocks and other river health effects.

2.2.2 Future water exploitation

The medium term projections for water use growth indicate that the current situation with respect to conflict between exploitation and river health will worsen significantly unless great care is taken. Agricultural water demands currently account for about 85% of total water use. These are projected to grow at about 4% per annum until 2010 (ONWRC 2003). Hydroelectricity production growth and associated dam construction will also have to continue at a rapid rate to allow the country to provide for the projected 10% per annum growth in power demands.

There are already approximately 500 "significant" reservoirs in Vietnam (over 1 million cubic metres or 10 metres in height), and 6 storages of more than 1000 million cubic metres (World Bank 2003). The catchment area of the 19 largest storages total about 12% of the total area of the country. There are many major new dams proposed to service hydro-electric and water supply requirements.

2.2.3 Management of dams

Many dams in Viet Nam are used for a variety of purposes, and operational priorities may switch depending on the time of year. For example, priorities in some dams switch from hydro-electricity production to flood control in the wet season. Hydro-electricity production involves storage of large inflows which are them released at rates compatible with power station capacities and power demands over long periods. flood control involves holding of water during times of flood and subsequent high rate releases of water to evacuate storages and restore airspace capacity as soon as inflows downstream of the dam drop below flood rates. Rules for operation of storages and switching of operational priorities are not fixed. Committees may alter release arrangements to satisfy changing priorities for electricity production or water for agriculture or other purposes. This adds uncertainty to the assessment of long-term impacts of dams on the downstream flow regime.

CONCLUSIONS - RIVER FLOWS AND WATER USE IMPACTS

- The degree to which dams, river regulation and water extractions affect flows in river systems in Viet Nam varies greatly between river systems.
- In a large proportion of the country water use and other flow regime changes are already at levels which are generally acknowledged to cause significant declines in river health without careful management.
- In many rivers a large proportion of river flows are regularly being extracted for use during the dry season.
- The scale and rapidity of new storage construction, the importance of hydro-electricity and the rate at which water extractions are growing makes it urgent that policies and assessment processes which properly consider the flows needed to maintain river health be determined and implemented as soon as possible.
- The multi-purpose nature of some dams, the lack of fixed operational rules and the likelihood that management may change over time makes the assessment of long-term impact of some dams difficult to determine. This may make it necessary to periodically review rules designed to provide flows needed to maintain river health.

3. Groundwater background

The exploitable yield of groundwater systems across the entire country has been quoted as being up to some 60 billion cubic metres per year (World Bank 2003, ONWRC 2003). However, it appears this figure is based on some very simple assumptions about country-wide recharge rates and geology. Calculations for areas where groundwater exploitation is of interest and there is some monitoring and geological information available indicate potential yields of around 6 to 7 billion cubic metres per annum. However, less than 1 billion cubic metres is based on detailed surveys which take into account both quality and quantity ONWRC 2003).

Advice from some officers in the Ministry of Natural Resources and Environment is that some calculations of yield that have been undertaken previously have assumed that that aquifers can be drawn down to empty over a 25 to 30 year period. This assumption, if it is still being made, seems contrary to the requirements of the 1998 Law on Water Resources (see section 5.1).

It is probable that yield calculations have not been able to take into account the connection between aquifers and rivers, and the effect that extractions in some areas could have on dry season river flows, and the impact of declines in aquifer water on domestic supply from wells and shallow bores.

Vietnam's groundwater resources are unevenly distributed. The potential supply available from unconsolidated sediments in the northern and southern deltas areas and some other regions is substantial. The central highlands basalts also appear to be another area with good groundwater potential. The supply available in other areas, notably the North and South Central Coast regions, is however likely to be much more limited.

Ground water is generally of good quality and able to meet requirements for domestic and drinking water, especially in mountainous areas. However, salinity intrusion occurs in some coastal areas and goes far inland to some provinces. Over-pumping and inflows from use of brackish water on fish farms is also a source of salinity problems in some coastal dune areas. In some areas of the southern and northern deltas, water is acidified and affected by iron. In some large cities such as Hanoi and Ho Chi Minh City as well as the Mekong River delta and industrial centres, ground water is contaminated by industrial and other pollution.

Only a small proportion of the currently known sources of supply are exploited – a figure of 5% is quoted in World Bank 2003. ONWRC quotes a figure of 'less than one billion cubic metres per year" as the volume extracted. Either way the general picture would appear to be that current extractions from most aquifers are low relative to yield. Groundwater is currently of most importance as a source of urban and domestic supply purposes. Industrial uses are however taking increasing volumes and groundwater is used for irrigation in some areas, notably in the Central highlands where it is used for cash crops.

The low overall use of groundwater compared to total potential yield does not mean that there are no current problems resulting from over use. There are serious concerns about dropping water levels and consequent aquifer compaction and subsidence in Hanoi, where levels dropped 8 metres between 1992 and 2002 and in Ho Chi Minh where levels dropped 16 metres between 1994 and 2003 (World Bank 2003). Surface subsidence in Hanoi has been occurring at up to 45 mm per year and is resulting in structural concerns with regard to buildings, roads and drainage works. Shortages of water are also said to have occurred in in the Central Highlands (World Bank 2003). The intention for Ha Noi is to move from groundwater to surface water over the next 5 or so years.

CONCLUSIONS - GROUNDWATER ASSESSMENT AND WATER USE IMPACTS

- Most current estimates of potential groundwater yield are of poor accuracy.
- Some assessments may have been done on the assumption that aquifers can be emptied over a 25 to 30 year period – this is contrary to the 1998 Law on Water Resources.
- Levels of groundwater use relative to potential yield appear low overall, however water level declines occurring in some areas indicates that extractions already greatly exceed sustainable yields from some aquifers or sections of aquifers.
- Problems with water quality in some areas also indicate that better management of pumping, among other measures, will be necessary to avoid further contamination of aquifers.

4. Other Imperatives for Management Change

4.1 PROTECTION OF DEPENDANT COMMUNITIES

The Government of Viet Nam has placed great emphasis on the economic development of the country, the improvement of living standards and the reduction of poverty. In pursuit of this there have been, and will continue to be, great efforts made to develop infrastructure to supply growing agricultural, industrial and domestic water needs.

However, the Government has also acknowledged the need for better consideration of the environmental and river health consequences of development and the very direct connection between environmental decline and the well being of many of the people in the country. For example, the Socio-economic Development Strategy for 2001 - 2010 states that "socio-economic is to be closely associated with environmental protection and improvement". The Government's Comprehensive Poverty Reduction and Growth Strategy also identified protection of the environment and preservation of natural resources as important to reducing poverty levels.

There are many issues relating to water which need to be considered and dealt with if the goals relating to sustainable development, environmental protection and optimising socio-economic benefits are to be achieved. These must include the preservation of flow regimes and aquifer water levels which are adequate to:

- ensure continuing long-term maintenance of processes that are essential to river health and productivity, for the benefit of current and future generations,
- prevent compaction of aquifers and declines water quality through acidification and saline intrusion and the consequent loss of water supply and other beneficial services which groundwater systems provide,
- maintain important aquatic ecosystems which depend on water from rivers or groundwater systems, and the socio-economic services which these ecosystems provide.

Viet Nam is conscious of pollution problems and appears intent on taking strong action to reduce pollution from a number of the most high impact industries. However, actions to reduce pollutants will be made much less effective if the ties between maintenance of adequate flow regimes and achieving good water quality are ignored. Some of these ties are direct and obvious, for example dilution and flushing of pollutants and mixing which sufficient to prevent eutrophication and other toxic chemical changes associated with low or no flow situations. However there are also many other links. Some result from the role played by plants and animals in the processing of organic matter and nutrients, others result from connections between flows and the erosion and accretion of sediment.

The connection between maintenance of the natural productivity of water sources and the socio-economic well being of many communities in Viet Nam is also stronger than in wealthier developed countries. Many communities depend on rivers for their supply of water for drinking and essential household needs. Rivers also provide them with fish and other food stuffs, and are their only source of water for the production of agricultural and animal products for household use. This strong link gives an added significance to "environmental flow" and water source protection decisions. Indeed the term environmental flow is something of a misnomer in relation to Viet Nam where it is not possible to divorce protection of a water source's "environmental" health from protection of the flows needed to maintain the direct human benefits that arise from good river health. Indeed this need is recognised by the importance attached to "water for living" in the 1998 Law on Water Resources (see section 5.1). For this reason the term river health flow has generally been used in this report in place of environmental flow to reinforce that the objective of improved flow management is wider than just environmental protection.

4.2 CONSEQUENCES OF DELAYING ACTION

Delaying measures needed to ensure flows are adequate to maintain river health and protect aquifers until impacts have become obvious is not a responsible management option from either an environmental or economic point of view. This is because:

1. once impacts have occurred they are often irreversible,
2. the connection between impacts and flow change may not be identified in time to take action and adjust management,
3. even partial mitigation of impacts once they have occurred can impose large costs on government, communities and future generations, and
4. much higher economic and social costs are involved with reductions in water supply yield or electricity production once development has already occurred.

Application of river health flow measures is also an important precursor to establishment of a stable licensing system.

If licensing of water supply structures or water extraction occurs before rules that protect river health flows have been established then licence holders need to be made aware that their water supply volume is not guaranteed in the long term. They can then build this uncertainty into their project design or business management decisions.

It is also important that licensing does not result in the Law on Water Resources' compensation provisions becoming an impediment to introduction of effective river health flow measures or a financial burden on government. Options for doing this include:

- restricting the total volume of extraction licences issued to a cautious amount,
- limiting the term of the licences, or
- applying conditions to licence that permit future adjustment of infrastructure operation rules or some reduction in water supply volumes without government compensation.

Effective river health flow rules are also important to the success of any water licence trading market. Once they are in place, they allow the government to provide those purchasing licences with greater surety regarding long term access to the nominated licence volume.

CONCLUSIONS - OTHER IMPERATIVES FOR MANAGEMENT CHANGE

- The government has acknowledged the link between economic development, environmental protection and alleviation of poverty
- Adequate flow regimes must be maintained in rivers, and pumping from aquifers effectively managed if river health and the long-term productivity of rivers and groundwater systems is to be maintained for current and future generations
- Protection of supplies of “water for living” is particularly important in Viet Nam
- Maintenance of adequate flow regimes is important to achieving the countries water quality objectives
- Delaying decisions increases the risks of irreversible damage to water source health and is likely to result in greater long term economic costs to the community, government and future generations
- Water licensing and water market processes will be of less benefit if river health flow decisions are postponed.

5. Legal/Policy environment

5.1 THE LAW ON WATER RESOURCES 1998

The 1998 Law on Water Resources provides a clear foundation for the implementation of limits on water extractions and measures to protect the environment and river health. it also establishes river basin plans as a means by which this is to be done.

The Law contains numerous references to obligations relating to the protection of water sources. Article 1 places a general responsibility on all organisations and individuals to protect the water source against deterioration or depletion. Article 8 prohibits "acts which cause the deterioration or serious depletion of the water resource". Article 10 obliges those who exploit or use a water resource to protect it.

Article 11 requires that "The State shall have a plan to" ….. "restore the deteriorated and depleted water source" and encourage use of water "rationally" so that the water resource is protected.

The requirement in Article 5 that "protection, exploitation and use of water" …. "must comply with the zoning of the river basin" while Article 20 (1) states that "The regulation and distribution of water resource for use purposes must be based on the planning of the river basin and the real potential of the water source".

Article 29 makes hydro-electric production subject to plans and environmental protection measures. It requires that "the building of hydroelectric works must comply with the planning of the river basin and the prescriptions on environmental protection" and that those using water for hydro-electricity "must comply with the process of operating and regulating water ratified by the competent State agency" and that they must ensure that negative third-party impacts are limited.

The protection of water sources also extends to underground water. Article 12 states that Organizations and individuals that exploit underground water must comply with the order and norms on … prevention against depression and sinking, on the protection of water-storing layers and the related environment" Article 34 (2) states that "The issue of permits for exploiting underground water must be based on the result of basic survey and prospects of underground water and its potential and reserve." Article 44(3) requires that "The …. exploitation of underground water in the coastal areas must ensure the prevention and fight against salinity infiltration for the underground water holding layers."

The Law also establishes a permit system. All water users, other than those taking water for small scale 'family" uses must "get permission from the competent State agencies".

Two other features of the Law are relevant to decisions about river health flows and water extraction limits.

The first is its requirement with respect to protection of "water for living". Article 20, which deals with Regulating and distributing water resource states that:

> "1. The regulation and distribution of water resource for use purposes must be based on the planning of the river basin and the real potential of the water source and must ensure the principle of fairness, reasonability and priority in the quantity and quality of water for living.
>
> 2. In case of water shortage, the regulation and distribution must give priority to the living purpose. For other use purposes, the regulation and distribution shall be made according to the percentage defined in the planning of the river basin and the principle of ensuring fairness and reasonability."

The second is its compensation provisions. Article 22 states that those who "exploit and use water" are entitled to compensation if "their permits for exploitation and use of water resource are withdrawn before term for … national and public interests reasons". They are also entitled to "lodge complaints and seek legal actions …. for acts of violation of the right to exploit and use water resource". As discussed in 4.2, this provides a further impetus to developing and implementing effective river health flow measures and limits to water extractions as soon as practicable.

5.2 DECREE ON IMPLEMENTATION OF THE LAW ON WATER RESOURCES

The Decree (No 179/1999 of 30 December 1999) restates much of the content of the 1998 Law on Water Resources. It does however strengthen the role of river basin plans and add some details regarding content. Article 9, directly links the granting of permits to the capacity of the "actual capacity of water sources".

5.3 LAW ON ENVIRONMENTAL PROTECTION 1993

Article 18 requires that those constructing or renovating structures must submit Environmental Impact Assessments (EIAs). In Article 17, the Law also requires those with "establishments" already in existence also have to submit EIAs. A recent review of EIAs and comments by government representatives however acknowledge that they were often of poor quality and that better guidance was required regarding their formulation.

5.4 MEKONG AGREEMENT

Article 3, titled "Protection of the Environment and Ecological Balance" requires Viet Nam to "protect the environment, natural resources, aquatic life and conditions, and ecological balance of the Mekong River Basin from pollution or other harmful effects resulting from any development plans and uses of water and related resources in the Basin."

Article 6, titled "Maintenance of Flows on the Mainstream" requires Viet Nam to "cooperate in the maintenance of the flows on the mainstream from diversions, storage releases, or other actions of a permanent nature; except in the cases of historically severe droughts and/or floods:
A. Of not less than the acceptable minimum monthly natural flow during each month of the dry season;
B. To enable the acceptable natural reverse flow of the Tonle Sap to take place during the wet season; and,

The Joint Committee, which is the implementation body of the Mekong River Commission, is in charge of developing the necessary guidelines for the location and levels of the flows.

Final rules for the management of the Mekong are to be based on an environmental flow assessment".

Article 7, titled "Prevention and Cessation of Harmful Effects" requires that Viet Nam "make every effort to avoid, minimize and mitigate harmful effects that might occur to the environment, especially the water quantity and quality, the aquatic (eco-system) conditions, and ecological balance of the river system, from the development and use of the Mekong River Basin water resources or discharge of wastes and return flows."

No formal national level arrangements similar to the Mekong Agreement exist in relation to the Red River or the other small international rivers which flow between Vietnam and surrounding countries.

5.5 AGENDA 21

The Prime minister's recent Agenda 21 Strategy decision reaffirmed the government's commitment to sustainable water development. Although much of the document was quite general and aspirational, several statements provide specific support to the setting of environmental flow rules and water use limits. In the "Sustainable use and protection of water resources" section the following are included as priority activity areas:

- water source management policies that balance the need to supply water for consumptive and hydro-electric purposes with the "the benefits of natural water and ecological system management criteria", and
- comprehensive environmental criteria on underground water, surface water, rivers, lakes, reservoirs and other wetland areas.

5.6 NATIONAL WATER RESOURCES STRATEGY

The Strategy is still under development. However it is likely that it will:

- lead to better definition the meaning of "water for living" contained in the 1998 Law on Water Resources and assign it absolute priority with respect to water sharing decisions,
- reference the link between the natural flow regime and protection of river health,
- emphasise the need to consider the link between maintenance of healthy water sources and resultant benefits to poor communities when making infrastructure and water management decisions,
- propose processes for better co-ordination of infra-structure development so that impacts are minimised and cost efficiencies achieved
- encourage consistent operation of storages
- propose that design and operation of all new storages take environmental release requirements into account,
- require that opportunities for provision of environmental releases from existing structures be explored,
- in relation to aquifers seek to reduce extractions where these currently exceed aquifer recharge rates and limit extraction growth in other aquifers to predetermined proportion of recharge,
- require that river basin plans establish rules which prevent groundwater extractions close to rivers and/or manage he timing of pumping so that impacts on dry season river flows are minimised.

CONCLUSIONS - LEGAL/POLICY ENVIRONMENT

- The Law on Water Resources and more recent policy statements provide a foundation for limiting water extractions and applying river health flow measures and for the incorporation of such measures into river basin plans.
- Groundwater resource assessment methods and practices in relation to exploitation (see 3) very clearly need to be overhauled to bring them into line with the requirements of the Law on Water Resources.
- These add to the general EIA processes applying to individual development proposals established by the Environmental Law.
- The only requirements in relation to the form such rules are the references contained in the Mekong Agreement. However, these are not so specific that they compel any particular form of assessment.
- The legal and policy statements are however all of a quite general and aspirational nature. There are few if any specific guidelines or measures in place and little practical action currently being taken to achieve the worthy intents embedded in the legal document.

6. Availability of data and information

Data is a vital ingredient in any assessment of water source capability, the likely effect of water extractions, the impact of new infrastructure and the effectiveness of alternative management rules.

There are 4 major types of information relating directly to the surface water sources that may be required in order to carry out a river health flow assessments:

1. hydrologic data – which is needed to establish how much water is present and how its availability will vary over time
2. infrastructure information – so that the impacts of dams and other infrastructure on the timing and volume of water flows can be assessed
3. water use data – so that the effect of extractions on river flows can be assessed
4. ecological information – so that the plants and animals present can be considered and the effects of flow regime change on them assessed

Water resources information in Viet Nam is said to be "relatively abundant" but its collection is fragmented and uncoordinated and there are difficulties in the extraction of information from some agencies.(ONWRC 2003).

The Department of Water Resource Management holds flow data for 173 gauging stations. The average length of flow record at each site is however only about 20 years. It is therefore likely that some relevant hydrologic information will generally be available, but it is will often require transposition and/or extension. There are however standard methods for doing this..

Information on the physical aspects of surface water infrastructure should be readily available from relevant authorities such as Electricity Viet Nam and the Ministry of Agriculture and Resource Development. It is however likely that reliable information on current and historic storage and release management arrangements will be more difficult to gather.

Data for major water users is available from those ministries and organisations responsible for the various water use sectors, for irrigation and rural water supply the Ministry of Agriculture and Rural Development, for urban water supply the Ministry of Construction and, for hydro power, Electricity of Viet Nam and the Ministry of Industry. Numerous uses also lie within the jurisdiction of provincial authorities and are monitored but to varying degrees. (VWRMAP 2004). Information for smaller scale users is likely to be very limited.

In many cases where river health assessments are required, water use information will be inadequate. The co-operation of agencies that have collected data will be critical to derivation of adequate water use data.

General ecological information on such things as fish species present etc is available however whether this is of a form that is useful for river health flow assessment purposes is not known. It is probable that specific knowledge regarding environmental responses to flow changes will be very limited..

Other types of information may also be required by some assessment processes, and these needs may extend to social and economic data.

For aquifers, the major types of information required in order to carry out an assessment relating to allowable extractions are:

1. hydrogeological data – which is needed to establish the size, type (confined, unconfined), water storage and transmission characteristics of an aquifer
2. site related water use data – so that the effect of current extractions can be assessed and any associated water level response information can be used to determine aquifer characteristics
3. location and capacity of pumping infrastructure and bore construction details – these are required to determine the possible scale of extractions and the aquifers being accessed
4. results of pumping tests and water level information – to assist in establishing recharge rates, sources of recharge and other aquifer characteristics
5. information regarding dependant ecosystems – so that the impacts of extractions on these systems can be considered when extraction management decisions are made

Information regarding 1 to 4 is patchy, particularly outside areas where exploitation is currently relatively high. It is probable that very little information is available regarding dependent ecosystem and river connections.

The following table comes from a recent summary of data and information activities in the water sector.

DATA	DATA COLLECTION	DATA ARCHIVING	LICENSING DATA
Hydrometeorological Data	There is a comprehensive hydrometeorological data network across Vietnam, mainly coordinated by HMS. However, the quality of the data is not up to international standards. Data measuring and recording technologies are outmoded.	HMS is mainly responsible for hydrometeorological data archiving, and apply some consistency to data management. Their computer systems are not up to international standards, however.	Surface water licensing has not yet been implemented in Vietnam, even though it is provided for in the Law on Water Resources.
Water Quality Data	Many ad hoc Water Quality sampling programs have been implemented, mainly on a project-by-project basis. Whether standards for sample collection, preservation and transportation have been adhered to is questionable.	Water Quality data is generally kept in simple systems (eg, spread-sheets) at laboratories, or departmental or project offices. There are no standards across Vietnam for Water Quality data management and archiving.	Wastewater discharge licensing has not yet been implemented in Vietnam, even though it is provided for in the Law on Water Resources

DATA	DATA COLLECTION	DATA ARCHIVING	LICENSING DATA
Groundwater Data	Groundwater monitoring networks have been established in the main aquifer areas, particularly in the Mekong and Red River deltas. As groundwater management issues increase in other areas, there will be an ongoing need to broaden the monitoring.	Several outmoded systems for GW data archiving exist. A GW data management and modelling system was recently developed by Haskoning for the Mekong Delta. This system could be extended to cover all of Vietnam.	Groundwater extraction wells are meant to be licensed by the Department of Agriculture and Rural Development, but this is not always carried out. Databases holding the licensing records may be held in local Department of Agriculture and Rural Development offices.
Environmental Data	National Environment Agency has a well established national program for collecting environmental data. Other data has been collected on a project-by-project basis.	National Environment Agency presumably has a system to store the data collected in its program. Other environmental data is generally kept in simple systems (eg, spread-sheets, maps) in departmental and project offices. There are no standards across Vietnam for environmental data management and archiving.	
Socio-Economic Data	A broad range of official socio-economic data are collected in Vietnam by various ministries, much of it down to commune level. Its overall accuracy has been questioned. Other S-E data has been collected by various NGOs and on a project-by-project basis/	Most of the official socio-economic data is held by the ministry that collects it. Presumably, NGOs keep their data in their own systems.	
Overall Data Coordination Arrangements	Currently the concept of custodianship has not been adopted in Vietnam. Responsibilities for ensuring that different types of datasets are managed and disseminated to meet user needs have not been allocated. Dataset types have not yet been properly defined in Vietnam.		

CONCLUSIONS – INFORMATION AVAILABILITY

- hydrologic data – is of reasonable quality and length and should provide an adequate basis for assessments – although extension or synthesis of data from nearby record is likely to be needed in many cases
- infrastructure information – data on the physical aspects of dams etc is good but information on management rules is likley to be more problematic.
- water use data – fragmented and incomplete.
- ecological information – limited

I suspect my conclusions in relation to groundwater data will be something like:

- hydrogeological data exists for individual bores, but, except for already heavily used aquifers in major cities, this has not generally yet been analysed in ways that make it useful for aquifer characterisation and subsequent use in assessments of yield.
- site related water use data – generally poor except for major developments.
- location and capacity of pumping infrastructure and bore construction details – poor except possibly for major developments?
- information regarding dependant ecosystems – very limited.

7. River Health/Environmental Flow Assessment - review and recommendations

7.1 INTRODUCTION

Environmental/river health flow assessments seek to answer the question of how much flow needs to remain, be released into or be restored to a river system to maintain or achieve a particular river health or environmental outcome. They may be carried out as part of a process for determining how to develop a water source, manage a piece of infrastructure or control water use in a way which provides an optimal mix of economic, social and environmental outcomes or as part of a process focussed only on river health or environmental improvement.

Assessments are never about protection or reinstatement of a perfect, complete and pristine 'natural' environment' – for this would require that no water use or flow regime changes occur and no infrastructure be built. However, the connection between the natural flow regime or features of it and maintenance of stream ecosystems and river function is so strong that many assessments use features of the natural flow regime as a starting point. The assumption made by all methodologies is that something less than or somewhat different to the natural flow regime can also maintain most natural features of the river or at least a desired subset of these features.

The connection between the portion of the flow regime or flow characteristic preserved and the river health outcome achieved is generally complex and non-linear. Many ecological and geomorphic functions will not occur at all until a certain flow threshold is reached and some plants and animals will show little change in numbers until the flow regime alterations pass a critical point. Therefore, assessment which focus on maintaining ecosystems rather than single species generally provide much more than a simple single flow volume recommendation.

Assessments may occur at the major basin, sub basin, river reach or individual project scale. They can also relate to all ecosystems potentially affected by river flow changes, or to particular ecosystems, or even to particular species whose protection is particularly desired – for example species that have been identified as 'endangered' or which provide particular economic benefits.

Most assessment methodologies only examine the environmental side of the environmental flow decision process. Some of the more recent "holistic" assessment methodologies go further and explicitly include consideration of social and economic outcomes.

Over 50 countries now use environmental flow assessment as a water management tool. Requirements to provide flows to protect and restore river ecosystems and protect river health are also increasingly appearing in national legislation. Examples are in Australia as part of recent water reforms, in South Africa associated with the new water laws, and in Europe in response to the European Water Directive (Arthington 2003).

7.2 AVAILABLE ASSESSMENT METHODOLOGIES

A large number and wide variety of assessment methodologies have been developed over the last 30 years. A recent global review (Tharme 2003) cites some 207 methodologies from some 44 countries. These vary greatly with respect to their objectives, complexity, the technical and scientific inputs they require, and the extent to which they incorporate other factors.

There are various ways to classify these assessment "methodologies". One of these is to categorize them as - methods, approaches or frameworks (Dyson et al 2003).

'Methods' are standardized technical assessments which generally provide a single recommended flow or flow regime.

'Approaches' may use a range of discipline experts and methods to produce a set of flow recommendations. These generally try to take a "holistic" view and provide advice regarding required flow regimes rather than a single flow recommendation. The recommendations usually aim at maintaining a particular environmental or river health state – although this state may not always be clearly or explicitly specified. Although these approaches still deal with the issue as a purely scientific problem they may provide decision makers with information about the river health outcomes that would result from a range of potential flow regimes.

Most of the methods and science based approaches can be placed into one of 4 categories (Tharme 2003):

- Hydrological methods. The recommendations provided by these methods are usually a function of one or more natural flow regime statistics.
- Hydraulic rating methods. These require development of relationships between flow and hydraulic variables (such as wetted perimeter or depth) that are believed to have environmental significance for the target river system. A threshold level of the environmentally significant hydraulic variable is then chosen and the required flow inferred from that value.
- Micro-habitat or habitat simulation methods. These require development of relationships between flows and presence of suitable hydraulic and habitat conditions, plus information about the habitat requirements of target species, to predict optimal or acceptable flow regimes.
- Holistic approaches. These aim to identify the essential features of the flow regime that strongly influence desired ecological, geomorphic or other river health outcomes for the river system. Recommended levels for each flow feature are then determined and coupled together to produce a recommended flow regime. Often the recommendations are also based on knowledge of the natural flow regime.

'Frameworks' are aimed at providing information to decision makers that can be used to help reach an optimal balance between river health, social and economic outcomes. They treat the issue as a trade-off process. They use methods or approaches relevant to each of these outcome areas to provide information to decision makers about the consequences of a range of possible management scenarios.

Tharme 2003 also refers to hybrid approaches. These have some of the characteristics of several of methods and approaches referred to above and generally have been developed for purposes related to specific ecosystems or species or other issues associated with river flow, such as recreation and aesthetics.

The methods, approaches and frameworks referred to above are discussed in more detail in the following section. Summaries and assessments of a number of the more prominent methodologies are also included in Appendix 1.

It is also useful to recognise that assessments may be prescriptive or interactive (Brown et al 2003). Prescriptive methodologies provide a single flow level or flow regime recommendation. Such methodologies are of most use where the only goals relate to water source health and these are simple, clear and agreed. Interactive methodologies can be used to provide information about a number of development or management options and allow a range of possible flow and river health outcomes to be explored. They therefore can also provide information of use in decision processes which seek to "optimise" economic and social and environmental outcomes.

7.2.1 Hydrological Methods

These include some of the simplest assessment methods. They rely on analysis of natural flow statistics. This generally uses existing historic flow data, adjusted where necessary to compensate for the effect of dams and water extractions. Where reliable computer models exist, these may also be used to produce natural flow data.

The natural flow data is analysed to find the flow rate equal to the statistic on which the method is based. The statistic used is usually one which is believed to result in a flow rate which is the minimum required to achieve a particular "level" of river health, permit target species to survive or allow some process to continue to occur. The statistic may be a flow percentile, but other forms of flow statistic are used by some methods

The methods discussed in Appendix 1 of this report are:

- The Tennant (also called the Montana) method.
- The Texas Concensus Three Zone Concept
- Range of Variability Approach (RVA)
- Natural flow indices

These methods can be carried out in the office without any additional ecological information or any site related data other than flow. However, only the Range of Variability Approach (RVA) could be used in Viet Nam without first checking the applicability of the methodologies and its flow recommendations to this country's rivers. Once checking and any necessary reformulation was carried out individual assessments using Tennant etc could be done quite rapidly.

The simpler methods, such as the Tennant method, only establish a single minimum flow point. Ecologists would generally agree that maintenance of river health requires provision of an adequate flow regime (see section 2.1 of this report) rather than a particular single flow. Methods which provide a single "critical" flow point may however be valuable in certain restricted circumstances. The primary potential uses for a hydrologic method in Viet Nam are likely to be:

- establishment of consistent flow levels at which extraction management measures are applied in unregulated rivers,
- as the flow component of a water use versus flow index that could be used for ranking the water use related risk to river health on unregulated rivers, or

- as the basis for setting of minimum release requirements for small dams or dams on systems where the harm caused by changes in river flow was likely to be of little importance – for example where flow changes were only significant over short reaches of river – or was related primarily to increases in the frequency of low or zero flows.

The Texas Concensus Three Zone Concept is of interest primarily because of the way in which it makes flow rules dependent on water supply risk, current flow conditions and time of year. Similar concepts have been used to derive flow rules for river health management purposes in Australia. In many circumstances in Viet Nam it may also be appropriate to formulate river health flow rules in ways which take into account the water supply situation as well as natural factors such as time of year and current flows.

The Range of Variability Approach (RVA) provides a default recommendation of one standard deviation either side of the mean for each of the 32 parameters it uses. However expert guidance should really be used in choosing the range of variability for each variable that is likely to produce the intended ecological and river health outcome. The Indicators of Hydrologic Alteration (IHA) are the set of indicators which the RVA approach utilises. They have a potential value on their own as a "powerful tool for the calculation of high information, non-redundant indices describing the major components of the flow regime" (Olden and Poff, 2003). They therefore could be used for assessing flow regime changes and the flow regime benefits of potential management measure.

7.2.2 Hydraulic Rating Methods

Hydraulic methods use calculated values of wetted perimeter, depth, velocity or other variables as indicators of satisfactory habitat. The required flows are determined by hydraulic calculations (Mannings or HEC).

Generally the objective is maintenance of fish habitat and, in particular, connectivity between pools. It is assumed that hydraulic conditions at hydraulic control points are good indicators of habitat condition and therefore that maintenance of flow at some minimum level (or greater) will maintain populations of the target species.

The wetted perimeter and R2Cross approaches were developed for small to medium unaltered pool and riffle rivers in the USA. These, and most other hydraulic approaches, are most applicable to unaltered alluvial systems where river flows rather than local geological features or human intervention determines the form of the river channel.

These hydraulic methods result in single minimum flow recommendation. As discussed in 2.1, ecologists would generally agree that maintenance of river health requires provision of an adequate flow regime rather than just provision of a particular minimum flow. Hydraulic methods could still however be applicable in Viet Nam in the circumstances outlined in 7.2.1 where they may also have the advantage that no historic or calculated hydrologic information is required to apply the methods. However, the limitations regarding the types of rivers to which they can be applied (unaltered, alluvial, pool and riffle) probably means that there are few river systems in Viet Nam to which the methods could be applied. Of further concern is the need for a high level of consistency in the choice of cross sections and in use of Mannings, HEC or other relevant flow estimation methods.

7.2.3 Habitat Simulation or Microhabitat Modelling Methods

These methods have generally been devised and applied in North America and Europe. They require creation of relationships between hydraulic conditions (depth, velocity etc) and "suitability" of habitat to target species. These relationships are then used to determine how habitat availability varies with flow and consequent changes in hydraulic conditions. This knowledge can also be used to determine how habitat availability will vary under flow regimes that might result from different development or management scenarios.

The methods target preservation of suitable habitat conditions for particular target species rather than preservation of ecosystems. They have generally been used in relation to fish species.

Detailed survey of channel form and river condition for the river systems or river reaches of interest is a necessary part of the process. Also central to it are the relationships between hydraulic condition, habitat type and species presence. These generally also require extensive collection of field data, preferably from the target river. Pre-determined relationships based on data acquired elsewhere may be used, however this of course diminishes the reliability of the approach.

These methods provide more ecologically valid information than simplistic hydrologic or hydraulic methods which provide only "minimum flow" recommendations. They also provide information that may be useful in determining the tradeoffs between environmental and economic outcomes associated with alternative development or management scenarios. There are however significant problems, other than cost, which work against use of these methods (see discussion of IFIM/PHABSIM in appendix 2).

IFIM/PHABSIM and similar closely related computer packages are the most frequently used habitat simulation methods. IFIM/PHABSIM is therefore the only habitat simulation method discussed in detail in Appendix 2.

7.2.4 Holistic Approaches

Holistic approaches are most prominent in South Africa and Australia. These countries lack the large scale commercial and recreational freshwater fisheries that exist in the USA and Canada. The emphasis in South Africa and Australia has therefore been on preservation of river ecosystems and overall river health rather than preservation of particular species such as salmon and trout. The techniques are now used in a number of countries in Europe, Asia and Latin America (Tharme 2003)

The original philosophy underlying holistic approaches was that water belonged to the environment but that, on occasions, there was "excess" water that could be taken or stored. Another way of saying this is that if the critical features of a natural flow regime can be identified then they can be combined into a new, but not entirely natural, flow regime that is capable of maintaining target ecosystems and natural functioning of the river system. This was modified over time to become volumes of water that could be taken without shifting the ecosystem from a state that approximated the pre-development situation to a less desirable state (Arthington 1998). Some holistic methodologies are now also used to predict probable river health changes that may result from flow regime changes.

There are a variety of methodologies that can be categorised as "holistic". Holistic methodologies may be either "bottom up" or "top down". 'Bottom-up' methods 'construct' a flow regime by adding desired flow components together starting from a baseline of zero flow. 'Top-down' methods start with the natural flow regime. They then try to determine either the degree of flow regime modification that can occur before river health impacts exceed some defined acceptable levels, or the relationship between flow regime modification and the degree and type of impacts.

Holistic approaches share a number of assumptions regarding the flow regime needed to maintain ecological sustainability or produce a particular ecological outcome (Gordon et al 2004):

- some elements of the natural flow regime cannot be scaled down but must be totally retained,
- some elements can be scaled down,
- some can be omitted altogether, and
- variability of flows should mimic the natural flow regime in cases where the goal relates to retention of aspects of natural ecosystems and functions.

High flow and low flow conditions are generally regarded as being more important than mid-range flows. This is because they stress some organisms, which prevents them from becoming dominant and because they provide opportunities for other organisms. Many geomorphic and ecological functions also do not occur at all until river levels or durations of flow at given levels exceeded certain threshold values (eg sediment movement, wetting of areas on higher parts of river banks and on floodplains, successful breeding or movement of organisms). High flow events which closely follow a similar sized event are often also regarded as of less importance as it is assumed the river process and ecosystem functions they trigger have already occurred.

Ecosystem components that are commonly considered include riverine geomorphology, hydraulic habitat, water quality, riparian and aquatic vegetation, macro-invertebrates, fish, and other vertebrates having some dependency upon the river and its riparian habitats (e.g. amphibians, reptiles, birds, mammals). The flow requirements of these components or the impact of flow changes on them can be evaluated using data derived from field studies, desktop assessments based on literature or experience elsewhere or use of expert opinion. Of course the reliability of impact projections drops as you move further away from relationships derived from actual observations at the site.

The South African Building Block Methodology or BBM (King et al. 2002) was the first holistic approach to be developed. It uses a highly structured expert panel approach to design a flow regime that it is believed will produce a pre-determined river health outcome.

Several expert and scientific panel methods have also been developed and applied in Australia. These have, however, not generally been as highly structured as the BBM approach.

The Benchmarking Methodology, which has been used in Australia, uses information about impacts that have occurred elsewhere to develop relationships between flow regime change and ecological and geomorphic response. An export panel is used to provide advice during the relationship development phase.

Downstream Response to Imposed Flow Transformations (DRIFT) framework, developed in South Africa, incorporates assessments of social and economic impacts as well as assessments of ecological impacts. Its ecological impact module requires a highly structured assessment of the impacts that would be expected with given changes in a range of hydrologic parameters. DRIFT facilitates assessment of a range of development and/or management options once the relationships between flow change and impacts have been set up. However, like all of the more complex assessment methods, the reliability of these impact projections is highly dependent on a good understanding of the relationship between flow and ecosystem behaviour.

The Flow Restoration Methodology and similar approaches undertaken in Australia have been used to assess how an existing regulated flow regime could be modified to restore some of the desired natural characteristics of a river. These approaches involve an assessment of the current impacts of flow regulation and use, and identification of possible flow and water use management options and potential river health benefits. These options are then computer modelled and the implications for water supply yields and long-term flow regime benefits are assessed.

Holistic river health flow assessments all require substantial amounts of data and technical assessment. Good information about the natural flow regime and the flow regime that would result from various development and management alternatives is necessary for all but the BBM methodology. Holistic assessments can however cope with uncertainty about ecological impact although the reliability of assessments is compromised if key information or understanding is missing.

The most advanced holistic approaches are relatively time consuming and costly. They have generally been applied to situations involving medium to large-scale developments and rivers of high conservation value or where supply impacts could be significant. They have also often been used in cases where there was substantial conflict between stakeholders about development or management decisions. Simpler approaches (e.g. expert panel assessments or more ad hoc "holistic methods") are appropriate for lower profile cases or situations where the options are very limited.

7.3 DISCUSSION AND CONCLUSIONS

7.3.1 How can river health flows be delivered

Before embarking on a discussion of the relative merits of the assessment methodologies outlined above, it is worth considering the possible management options that might be used to deliver or preserve a particular flow regime. Management options fall into two broad groups.

The first can be termed "active" management options. They affect the volume of water which enters the river system, and are therefore only applicable only to regulated river systems. Such rules can be:

- dam operation rules –which specify particular operational standards such as minimum release rates or limits on the rate at which releases may be altered,
- water sharing rules – rules which set aside a portion of the available water which can then be used to make releases for river health purposes, generally when predetermined circumstances occur,
- inflow sharing rules – rules which require that all or part of the natural inflows to a storage be passed through the dam for the benefit of the river health downstream.

The second can be termed "passive" management options. They affect the volume of water that can be taken out of the river system – and therefore the portion of the flow entering the system that remains available for environmental protection purposes. Passive rules can be applied to either regulated or unregulated river systems. Such rules can involve:

- limits on the volume that may be taken out over a particular prescribed period, or
- reduction or suspension of extraction rights at particular times of the year or when flows drop to prescribed levels.

There are generally a number of possible management options that could be used for achieving a particular change in the flow regime of a regulated river. It is, however, often difficult to assess the long-term flow regime and water supply impact of any particular rule. As well, two rules which deliver the same river flow impact may have quite different impacts on water supply and economic outcomes. Because of this there is often no alternative but to use computer simulation modelling techniques to determine the most appropriate river health flow rules for regulated river systems.

In unregulated systems only passive management options can be used and much simpler techniques can be employed to determine river flow and water supply outcomes.

7.3.2 Factors affecting the choice made

A comparison of water use and river flows across Viet Nam (see 2.2.1) indicates that water exploitation in many of Viet Nam's rivers is already at levels where significant river health damage will occur without careful management. It is also inevitable that there will be continuing rapid growth in water extractions and water storage and flow management infrastructure. Decisions about infrastructure development and water extraction management for most of Viet Nam's rivers will seldom be about the limits that need to be applied to maintain the river in a close to natural state. What they will instead need to be about is reducing river health damage and striking a better balance between environmental, economic and social outcomes.

No one approach will suit all situations and there are a wide variety of factors that will affect the form and detail river health flow measures of any assessment associated with their formulation. However, I believe the major factor is whether the river is regulated or unregulated. The reasons for this are outlined in the following table:

FACTOR	UNREGULATED RIVER	REGULATED RIVER
Complexity of flow regime impacts	Significant flow impacts are usually restricted to loss of flow from the low flow portions of the flow regime. The medium and high flow regime is normally relatively intact and there is little change in seasonality or most flow variability statistics.	Flow impacts may be complex and involve both losses and additions of flows at particular times. Impacts will affect the medium flow portions of the flow regime and may also affect high flows if the storage is large. Seasonality may be altered and short term variability of flows is usually also affected.
Scale of impacts	Generally not as large as in regulated rivers.	Generally larger than in unregulated rivers
Options for adjusting flow regime outcomes	The only options involve restrictions on extractions.	Options may include changes to dam operation, water sharing rules, extraction rules or some combination.
Economic consequences	Usually relatively easy to assess as the likely impact of flow restrictions on diversions and economic outcomes.	Different options may affect different groups in the community and have quite different economic impacts even though the flow regime impacts are the same

7.3.3 Unregulated Rivers

As indicated above, in unregulated rivers, the only way in which the flow regime can be adjusted is through restrictions on extractions. This can only have a significant impact on flows, and therefore on river health outcomes, when extractions are significantly and critically altering flows – which is almost always only at low flow times. It is also worth noting that the individual user who have to be controlled are generally small scale and numerous. Monitoring costs and other management difficulties makes it unlikely that any but the simplest management rules could be successfully applied to them.

In Viet Nam there is a second imperative, one that is clearly enshrined in the 1998 Law on Water Resources. This is that priority must be given to protection of the quantity and quality of water for living particularly during times of water shortage.

Currently there are no management rules or processes in place in Viet Nam's rivers which give effect to the Law on Water Resources' "water for living" requirements. , The water strategy will be seeking to have management measures put in place in all rivers to protect water for living. The most likely means for achieving this will be by restricting or prohibiting extractions for lower priority purposes in low flow periods. To do this will probably require licensing of extractions for these lower priority purposes. Extraction restrictions can then be specified on these licences or extraction can be made subject to the announcement of restrictions at critical times. Clearly ensuring compliance with restrictions will be a major challenge however.

Protecting both the quality and quantity of "water for living" along the full length of a river system should go a long way toward improving flow related river health and environmental outcomes in dry times. There should also be no need to justify the restrictions environmentally or to have to counter economic hardship arguments that could no doubt be mounted by lower priority water users who would be affected by extraction restrictions.

Therefore the logical first step, prior to any assessment of river health water needs, is to establish extraction management rules which protect the quantity and quality of water for living from impacts caused by extraction of water for lower priority purposes. Once the activities that are covered by "water for living" are clearly established it should not be too difficult to determine the quantities of water required for these purposes. The more difficult assessment will be whether additional protection of flows is needed to minimise water quality problems that arise when flow rates decline. Such assessments will need to take into account existing pollution loads and local hydraulic conditions.

In unregulated rivers, significant river health protection should result from management measures which secure the quantity and quality of flow needed to satisfy water for living requirements. Such measures should improve connectivity between river sections and reduce flow related water quality declines in rivers where dry season extractions are currently accounting for a major portion of dry time flows.

The questions that then need to be addressed are whether there are likely to be any ecological reasons for applying stronger restrictions on extractions during low flow periods and, if there are, what assessment methodology is appropriate for determining them.

With respect to the first question, species present in those rivers in Viet Nam that are subject to very low dry season flows must have a good tolerance for such conditions. There are also no obvious high profile fish or other species, such as trout or salmon, with particular identified flow needs that could drive decisions in favour of stronger protection measures in unregulated rivers. Given this, and the improvements that would arise from protection of "water for living" flows, it is my judgement that no additional river health flow measures would generally be justified or be likely to win approval in the face of the strong economic arguments that would be mounted against more severe restrictions.

If this conclusion is true it makes it unnecessary to deal with the second question, regarding appropriate assessment methodologies for unregulated rivers.

7.3.4 Regulated rivers

As already discussed in 7.4.1, the flow regime impacts in regulated rivers are generally much more complex and of a greater scale than those in unregulated rivers, the options for adjusting the flow regime much greater and the economic consequence more variable. Protection of flows needed to meet water for living requirements is therefore unlikely to significantly reduce flow regime change or alter the impacts of change on river health. To do this will require more substantial changes to dam and/or water extraction management. Therefore some form of river health flow assessment will be required.

One practical advantage, compared to unregulated rivers, is that there are generally only a small number structures whose operation needs to be monitored in detail. A few major extraction points may also account for a large proportion of total water diversions and use. It should therefore generally be much easier to implement complex management rules and assess compliance on regulated rivers than on unregulated rivers.

The factors that I believe are most important in determining the most appropriate methodology for Viet Nam's regulated rivers are:

1. the need to consider environmental issues as related to protection of ecosystems not protection of singles species,
2. the variable and generally limited ecological information that is available,
3. the large amount of proposed new development, and
4. the importance of river health protection to the long-term welfare of many communities and the varied nature of the dependences that they have.

Almost all ecologists would now agree that while "minimum flow" rules might provide some useful protection benefits for some fish species, they are of very limited value in relation to long-term ecosystem protection. What is important is maintenance of flow regime that contains as many as possible of the critical elements of the natural flow regime.

For this reason alone I would contend that none of the methodologies that produce a single minimum flow recommendation are of value in relation to Viet Nam's regulated rivers. There are however other reasons for rejecting these approaches. Even though the hydrologic and hydraulic methods that have been used to develop "minimum flow" recommendations are simple, they give inconsistent results even when applied to a single region (see Appendix 3). It is also doubtful whether the available ecological information is sufficient to allow the sensible and agreed modification of these rules to suit Viet Nam.

Habitat simulation methods are more ecologically valid than simplistic single value "minimum flow" methods. They can also provide data that is useful as the environmental input into decisions about tradeoffs between economic, social and environmental outcomes. However I do not believe they provide an adequate means for assessing river health flows for the regulated rivers of Viet Nam.

Habitat simulation methods are still targeted at the requirements of particular species rather than general ecosystem health, and even there fail to address flow variability factors that affecting the reproduction and migration behaviours of their target species. they certainly do not address the flow variability factors needed to maintain ecosystems and associated geomorphic issues. The processes involved in determining "suitability indexes" for Viet Nam's species are also likely to be subject to many confounding factors, such as the impact of fishing, water quality changes etc . The study process is also costly and time consuming.

That leaves only the Range of Variability Approach (see Appendix 1 for details) and the various Holistic approaches as potential methodologies.

The Range of Variability approach facilitates testing and development of environmental flow rules that aim at retaining critical elements of the natural flow regime. However ecological input is required to nominate "acceptable" variations from natural and draw, assess the relative importance of changes in one parameter versus another and draw ecological impact conclusions. RVA and the Indicators of Hydraulic Alteration (IHA) statistical analysis package can therefore really only be used with any confidence for the design of environmental flow rules if they are incorporated into some form of "holistic" approach.

That leaves only the Holistic Approaches. These do facilitate consideration of the whole riverine ecosystem, not just single species. Reliable outcomes depend on good information about the links between the environment and the flow regime. However, the processes do allow for expert opinion to be incorporated. They therefore provide opportunity for pooling of understanding and information and allow best use to be made of whatever information there is available. The approaches also provide information that can be used to inform communities about likely impacts and benefits.

Before discussing the applicability of these approaches, it is worth considering the two general situations in which they could be used. The first is in relation to existing dams and river regulation, the second is in relation to new projects. The table below sets out some of the differences between these two situations.

FACTOR	EXISTING	PROPOSED
Opportunities to modify flow regime outcomes	Usually limited – structure locations cannot be moved, sizes can generally not be altered and modifications are usually costly. As well, downstream development that depends on continued access to water has generally usually occurred.	May be substantial opportunities. This may even extend to changes in location, size and configuration of dams and other structures and limitations on allowable growth in downstream water use.
Likely funding available to support assessment process	Direct new government funding would be required.	Funding required is generally small relative to total project cost. Project donors may be willing to fully or partially fund assessments to ensure they can demonstrate to critics that environmental concerns are being properly addressed.
Starting point for assessment	The current, altered flow regime and already altered downstream environment.	The current flow regime and downstream environment, which may be largely unaltered by flow changes if the river is currently unregulated.

Likely support for environmental flow rules	Unless the existing impacts are large and a substantial portion of the population who would be affected is aware of them, it is likely that any proposals for large scale changes will have many more opponents than supporter.	If possible impacts can be explained it is likely that there will be significant support for efforts to alter developments or water management arrangements.

Of the holistic approaches reviewed, the most comprehensive is the Downstream Response to Imposed Flow Transformation (DRIFT) approach developed in South Africa. Benefits it offers which most other holistic methodologies do not are:

- it provides an efficient and structured and well documented process for relating flow regime change to ecological impact,
- it is a "top down" process that doesn't rely on any initial definition of desired outcomes, it is therefore useful where the goal is to "optimise"
- it explicitly considers and requires quantification of impacts on household services such as water supply, food sources etc
- once the relationships between flow regime change and consequences are developed, the consequences of any number of future flow regimes arising from potential management or development scenarios can be assessed quickly
- it allows prediction uncertainties to be recognised and incorporated into the information provided to decision makers

To do it well however involves considerable cost and time and data input. It is therefore probably most suitable to situations where money is likely to be available to properly support the assessment and the potential benefits of such a detailed process are worth the effort involved. This means that a DRIFT assessment would be most justified in relation to new projects, and would, in any case, provide much of the information that should be incorporated into Environmental Impact Assessments. As mentioned in 5.3, a recent review of environmental impact assessments indicated many were of poor quality. A requirement to undertake DRIFT may assist in improving standards in relation to new water resource projects. For existing development, use of DRIFT would only be justified where major management changes to operation or structures were possible and being contemplated, and where the potential impacts or benefits were considerable.

For existing situations where the changes and potential impacts were smaller the Flow Restoration Methodology, and similar approaches used in such investigations in Australia may be more appropriate. Such an approach can be structured in each case to focus only on the type and scale of changes that can reasonably be contemplated and on those river health improvements that are most strongly desired. There is really no well developed "off the shelf" model for flow restoration assessments, which is probably not a serious shortcoming as it is probably beneficial to tailor the approach each set of circumstances. However, it should be possible to establish a general outline that could be used to guide such process in Viet Nam. Such a process could use the Indicators of Hydrologic Alteration as the basic set of flow regime comparison statistics.

7.4 SUMMARY OF RECOMMENDATIONS

For unregulated rivers:

- do not carry out any environmental assessments
- instead devise procedures for assessing "water for living" requirements with respect to both quantity protection and flow related quality protection
- institute management which restricts lower priority uses of water whenever maintenance of adequate flow to service water for living requirements is threatened

For regulated rivers – new development

- Require use of a methodology based on the South African DRIFT process.

For regulated rivers – existing development and water use

- Where major changes are being contemplated or potential impacts are large require use of a methodology based on the South African DRIFT process

Where only minor changes are being contemplated, changes are of a very limited type or potential impacts are small, a Flow Restoration Approach should be used together with any other assessments that may be needed to inform decision makers regarding the scale of any related economic or social impacts.

8. Groundwater methods/ approaches

8.1 INTRODUCTION

There is no accepted worldwide definition of "sustainable yield" for groundwater systems.

Most definitions are aimed at sustaining the long-term benefits of aquifers as a source of reliable, uninterrupted water supply. The considerations in relation to setting sustainable extraction rules are therefore:

1. rate of recharge,
2. maintenance of structural integrity of the aquifer – prevention of compaction
3. prevention of water quality deterioration

More recently efforts have been made to incorporate the needs of dependent ecosystems. The most obvious examples are ecosystems such as wetlands and limestone cave systems. The most common dependent ecosystems are, however, rivers which are heavily depend on groundwater inflows for maintenance of flow during dry periods. This connection is undoubtedly a very strong one in Viet Nam.

The exception to this is where the aquifer is disconnected from surface sources of recharge and the water in the aquifer is "fossil water". In such cases any pumping is unsustainable and the management decision is really only about whether to exploit the resource now or reserve it for future use. This situation generally only occurs in arid areas- so it is doubtful that there are any examples in Viet Nam.

The connection between dry season river flows and groundwater in Viet Nam is a more critical consideration than in many other countries because of the importance of rivers as a direct source of "water for living" and as a source of fish and other food.

8.2 ASSESSMENT METHODOLOGIES

It is not possible to accurately assess the maximum long-term level of extraction that a groundwater system can sustain, without damage to its structural integrity or water quality decline, without detailed understanding of its response to extraction. The only way in which this can be obtained is through a sufficiently detailed groundwater computer model which can adequately represent the hydraulic characteristics of the system and its connection with the surface water system.

There are a many groundwater computer models in use throughout the world. However, it is beyond the scope of this project to try to assess which one or more are most suitable for use in Viet Nam. However, what can be said is, that the construction of a reliable groundwater model for any aquifer system can be a time consuming and expensive task. It is also one that requires good quality and well analysed information concerning aquifer characteristics. For a model to be dependable, it also generally true to say that there should be a reasonable period of water use and aquifer response information available to permit model calibration.

It is however only necessary to go to the cost of construction of a computer model in circumstances where:

1. there is some significant risk that damage to an aquifer will occur as a result of current or anticipated extraction,
2. a valuable dependent ecosystem is at stake,
3. or where water extractions from an aquifer may interfere with maintenance of dry season flows in rivers.

Given the low level of extractions relative to current estimates of yield, it is unlikely that circumstance 1 presently exists for most aquifer systems in Viet Nam.

In the absence of a computer model, the only reasonable approach is to put in place a management regime that limits these risks to a low level. Such a regime needs to:

1. limit total extractions to a level which will not cause an overall decline in aquifer water levels, which means limiting allowable extractions to a conservative estimate of recharge,
2. prevent localised declines in aquifer levels that might cause problems with water quality, loss of dry time flows from rivers or loss of supply to dependent ecosystems,
3. trigger the construction of a computer model when the existing or authorised level of extractions reaches the limit set by 1.

The limit needed to achieve 1 must be based on a conservative estimate of recharge. Recharge of aquifers from rivers and overbank flows are best assessed via a computer model which can adequately link the surface and groundwater systems. In the absence of such a model, the only source of recharge that can be assumed with confidence is rainfall.

Providing extractions do not exceed aquifer recharge, local declines in aquifer levels will, for all practical purposes, reflect the cone of depression associated with each bore. The extent of the cone of depression of each bore is a function of the pumping rate and the transmissivity of the aquifer and is relatively easily calculated. This means that once issue 1 is resolved, protection against the problems listed in 2 can be achieved via controls on bore locations that ensure their cone of depression will not intersect rivers, dependent ecosystems and areas of saline of poor quality water will not be drawn into the aquifer. In the absence of such calculations standard conservative setback rules which prohibit bores within a specified distance of nominated sensitive areas.

8.3 RECOMMENDATIONS

That for all aquifer systems where no reliable computer currently exists and there are no apparent problems related to over extraction:

- interim sustainable limits be calculated based on conservative assumptions regarding recharge from rainfall only,
- that a procedure for assessing likely cones of depression and appropriate setback rules or conservative standard setback rules be developed, and
- that a management regime be put in place which establishes a permit and management system which ensures that limits and setback rules are observed.

That for all aquifer systems where a reliable computer currently exists, there are already problems related to over extraction or potential extractions exceed the limits set using the procedure outlined above:

- limits on allowable extractions be calculated using computer models,
- that these calculations be based on the assumption that the management goal is to ensure the aquifer remain a long-term source of good quality water, and
- that such calculations take into account impacts on dry season river flows and any identified dependent ecosystems.

Further recommendations would be that:

- restrictions be applied to extractions under any permits issued to existing bores which are within allowable setback distances of rivers and that these which mirror any restrictions applied to permits to extract water from the river itself, and
- that existing bores within setback distances from other sensitive areas be progressively eliminated or made subject to rules which appropriately limit the risk to these sensitive areas..

Appendix 1 - Glossary

cone of depression	The conical-shaped depression of the water table around a pumping well caused by the withdrawal of water.
endemic species	Those species of plants and animals that were present before introduction of new species by humans
eutrophication	This occurs when the concentration of plant nutrients in water bodies, such as lakes, estuaries, or slow-moving streams reach levels that that stimulate excessive growth of algae and weeds. These then die and decompose with the result that dissolved oxygen levels in the water may reduce to levels that kill fish and other organisms.
flow percentile	In this report the flow percentile indicates the percentage of time that the flow is equalled or exceeded in a river. For example flows in a river are equal to or greater than the 50th percentile flow 50% of the time.
natural flow	The flow that would occur in a river if there were no dams or other water management infrastructure and there was no extraction of water from the river.
natural flow regime	The pattern of flows that occurs or would be expected under natural flow conditions. It is generally derived from analysis of historic flow data, with appropriate adjustments to account for any significant flow changes that have resulted from upstream dams and water use. Computer models, set to represent natural flow conditions may also be used to produce natural flow data.
regulation	In the context of rivers it means the storage of water behind dams and weirs and its subsequent release, as required, to meet downstream water demands.
regulated river	Is a river whose flows are at least partially influenced by storage and release of water by dams or weirs.
yield	The volume of water which a river can provide with a particular combination of - dams and other water supply infrastructure, - irrigation and other water use development, and - management rules
unconsolidated sediments	Material derived from the disintegration and erosion of consolidated rocks on the land's surface, as well as sediments deposited by coastal and glacial processes. Unconsolidated materials include, in order of increasing grain size, clay, silt, sand, and gravel.
unregulated river	Is a river whose flows are not influenced by storage and release of water by dams or weirs, although they may be affected by extraction of water.

Appendix 2 – River Health/Environmental Flow Assessment Methodologies

TENNANT OR MONTANA METHOD

Where developed

USA

Where applied

Widely used in the USA, but it has also been used in many other countries, frequently with modifications based on local hydrologic, geomorphologic or ecological observations and circumstances.

Description

Hydrologic method –interactive

The Tennant method establishes a simple look up table which relates expected river condition to streamflow. The streamflows nominated are proportions of the long-term average flow.

Note: Some authors refer to the Tennant/Montana method as providing a relationship between expected river condition and the proportion of the Mean Annual Flow. This could be taken to mean that the Montana Method is relating the total volume of flows present over a year to expected condition. This is not the case. The relationships established by the Tennant/Montana method provide an instantaneous flow rate that is the minimum that the authors say should be maintained at all times to sustain the nominated level of river condition. They do not refer average flows rates over a year or any other long-term period.

The original method cited seven expected conditions and required flow rates. The expected conditions were based on observations of circumstances in rivers in streams in Montana, Wyoming and Nebraska at different flow levels.

The finding from the observations was that when flows were expressed as a proportion of the average flow the circumstances at the sample sites were very similar for comparable flows. For example, when flows were less than 10% of average flow gravel bars were exposed, fish were concentrated into deep pools and large fish were unable to move across riffles. These circumstances were said to represent "poor" conditions. By 30 % of the average flow most substrate was found to be covered. This was said to be a "fair" condition. Similar somewhat subjective judgements were made regarding river conditions at higher flow levels. The highest of the Tennant/Montana recommendations is a flushing flow (equal to 200% of average flow), rather than a flow that it recommends be maintained.

Information required to apply technique

An accepted relationship between average annual flow and habitat condition.

Good quality natural flow data or reliable estimated data..

Output produced

Recommended minimum flow for maintenance of a target environmental condition.

Strengths

Relatively simple and low cost to apply and requires no fieldwork once any needed recalibration is carried out.

Weaknesses

The implicit assumption of the Tennant method is that a stable flow of some nominated level, with occasional freshes, will suffice to preserve a river and its dependent ecosystems in the target state over the long-term. This simplistic view would not be supported by ecological scientist as a flow regime that is adequate to support natural river ecosystems or river health as it lacks the necessary flow variability and range of flows.

It requires that the general form of the river under assessment be similar to those on which Tennant's method was based. It also requires that the relationship between the average flow volume in the river and the flow needed to perform the environmental functions on the methods "fair", "good" etc ratings be similar to the relationship in the streams Tennant studied. It is quite likely this is not the case in most streams in Viet Nam.

The method depends on the availability of sufficient good quality streamflow data or some other means by which to establish a reliable estimate of the average flow at a site.

Requirements to adapt to Viet Nam

There are many differences between the hydrology and geomorphology of streams in Viet Nam and those in the United States and most other locations where the Montana method, or variations on it, have been employed. It is therefore likely that the relationship between average flow and the flows which indicate the poor, fair or good habitat conditions on which the method is based would be different here. It would be dangerous to adopt the method recommendations without an assessment of their validity to this country.

The hydrology of Viet Nam is also far from homogenous. The same comment applies to river geomorphology. Some researchers (Orth 1981) have shown that, even within the central USA, the differences are sufficient to warrant recalibration. Experience overseas demonstrates that a number of calibrations would be required to cover a country like Vietnam.

Calibration of the method to a range of local circumstances would therefore be needed. This would require expert assessment of the relationship between flow and habitat condition at many locations (say a minimum of 10 locations for each hydrologic/geomorphic type).

It would also require that high quality, reasonably long term flow data be available at sites used to develop the relationships. Long term data would, of course, also be required at each site for which flow recommendations were to be developed.

Suitable for use in assessment of management options/ planning negotiations/ interaction with stakeholders and public

Of little value.

Suitability in Viet Nam

Not suitable for establishing comprehensive environmental flow rules for major storages or regulated rivers.

May be of some limited use in unregulated rivers in relation to low priority uses of water, however, the method would not seem to offer any particular advantage over rules based on low flow percentiles. Percentiles may in fact be more indicative of stressful conditions for fish and other aspects of river health than a statistic based on average flows. This is because the average flow is generally heavily dominated by flood and very high flow periods of the year.

INDICATORS OF HYDROLOGIC ALTERATION (IHA)

RANGE OF VARIABILITY (RVA) METHOD/

Where developed

USA

Where applied

IHA software has been used for impact evaluation purposes and research purposes in many locations in the USA and on some sites in Canada, Scotland, south Africa and Germany. The RVA method has also been used to develop or assess flow management options in some systems.

Description

hydrologic method – top down and interactive

The IHA Analysis (Richter et al) was developed by the Nature Conservancy to facilitate consistent assessment of the characteristics of a flow regime and assessment of changes in flow regimes that have resulted from dams, water extractions or land use changes. There are 32 hydrologic parameters used which are claimed to have ecological significance. They can be grouped into 5 categories:

1. The magnitude of monthly water conditions – the mean flow value for each calendar month
2. magnitude and duration of annual extreme water conditions – annual maxima and minima of various durations
3. Timing of the annual extreme flow – maxima and minima
4. Frequency and duration of high and low pulses
5. Rate and frequency of water condition changes – no of rises and falls and the mean rate of change

Any period of data can be used (although this affects whether some of the duration statistics can be produced). Flow levels or flow volumes can be used.

The output of the assessment is a time series of annual variations in the value of each of the flow statistics over the analysis period, together with the average value and measures of variation (standard deviation or co-efficient of variation). These can be displayed graphically to demonstrate the scale of change.

The RVA uses the IHA parameters. The premise is that there is a strong relationship between maintaining natural flow variability within or close to its natural variability and long term retention of natural ecosystems and maintenance of natural river processes and form The method is therefore suited to circumstances where these are the management goals. The method bases the choice of flow management targets on the statistics generated via IHA analysis. Where possible expert opinion or ecological studies should be used to provide management targets and assist in the choice of environmentally optimal flow management options. The developers (Richter et al, 1997) recommend that RVA generated targets and the effectiveness of management rules applied in each situation be confirmed by suitable monitoring programs and that the results of these be used to adjust targets or rules if required.

Note the software and users guide is available from:

http://www.freshwaters.org/tools/

Information required to apply technique

IHA - An adequate length (20 years plus) of reliable flow data for the assessment site. This can be either recorded at the site or generated data. Computer models or other flow estimation techniques which are used to generate data must however be capable of providing accurately representations of short term flow variability.

Where IHA is used to compare flow record from different data periods (i.e. actual flow record from say pre and post dam periods) assessments of data from adjacent rivers not subject to flow related developments or other methods (eg rainfall comparison) should be used to determine whether there were climate variations. Appropriate consideration needs to be taken of any identified climate variations.

RVA – availability of expert opinion of research information concerning the effect on river health of changes in flow regimes greatly enhance the dependability of the RVA method.

Output produced

IHA – provides ecologically meaningful statistics concerning natural and altered flow regime characteristics

RVA – provides flow regime targets for environmental flow measures.

Strengths

IHA parameters provide a consistent set of hydrologic impact/benefit measures and therefore a stable basis for consideration of management options.

The parameters used address the range of flow variability parameters generally thought important by ecologists and therefore should suit management decisions aimed at protection of ecosystems rather than specific species. A recent review of 171 currently available hydrologic indices (Olden and Poff, 2003) concluded that IHA provided a "powerful tool for the calculation of high information, non-redundant indices describing the major components of the flow regime".

RVA allows development of environmental flow recommendations across whole of flow regime in the absence of knowledge of species or ecosystems present or their "requirements".

Weakness

Requires good quality recorded or estimated hydrologic data (preferably of 20years plus duration) for reliable assessment of IHA parameters for natural flow conditions.

Requires a computer model to allow testing of flow management options against flow targets and therefore to allow design of system management rules.

Lack of expert guidance in choice of acceptable range of values for IHA parameters may lead to concentration on wrong elements of flow regime change.

In the absence of expert guidance it is not possible to assess the importance of changes in a parameter or the relative importance of changes in one parameter versus another.

Requirements to adapt to Viet Nam

IHA –None

RVA –expert opinion regarding the impact of changes in the various flow parameters in the rivers of Viet Nam or other similar rivers would be of great assistance in assessing ranges of acceptable change to parameters and therefore for development of environmental flow rules for particular systems.

Suitable for interaction with stakeholders/public etc

Useful if the connection between the IHA statistic and river system impact can be clearly articulated or where clear connections have been demonstrated elsewhere.

Suitability to water planning in Viet Nam

IHA parameters would appear to be of value for:

- consistent and ecologically meaningful assessment of the hydrologic impacts of water use development and the extent of impacts and therefore the possible long-term ecological effect of flow changes, and
- ranking of systems and sections of rivers with respect to hydrologic impact.

In the longer term, the IHA software may assist research into the relationships between river health changes and flow changes in Viet Nam by providing a consistent basis for identifying hydrologic changes.

The RVA method may provide a useful method for assessing alternative management options for regulated river systems and new developments, particularly where little specific ecological information is available. However some form of "holistic" approach add-on (such as an expert panel) is still required to make recommendations and assess results.

PERCENTILES AND OTHER NATURAL FLOW INDICES/

Where developed

Many countries

Where applied

Many countries

Description

hydrologic method – generally prescriptive

There are many techniques which set the "minimum environmental flow" as some proportion of the long term average natural flow, a natural flow duration curve value or some other more complex natural flow statistic (for example the 7 day minimum flow with a 10 year return period). The origin a number of these values is sometimes obscure and often quite arbitrary. The indices have only general ecological relevance.

Information required to apply technique

An adequate length of reliable recorded or constructed flow data for the assessment site. The length required will depend on the statistic used and on the variability of the climate in the region under assessment.

Reliable estimates of statistics related to more extreme flow statistics would require longer periods of historic flow record. Computer modelling data or other constructed flow data would be expected to be least reliable in relation to assessment of more extreme flow statistics.

Output produced

A single environmental flow value.

Strengths

Low time, cost and data requirements and limited specialist expertise required.

Weakness

The approach is simplistic and really only relevant, even for impact ranking purposes, in unregulated rivers where the only significant flow regime impact is generally loss of flow in naturally low flow periods.

Requirements to adapt to Viet Nam

A flow statistic that was suited to the hydrologic circumstances occurring in Viet Nam and which was sensitive to the scale of consumption that was occurring would need to be determined.

It is therefore likely that such a statistic would be one which relates only to low flow periods of the year in a basin and to median or less frequent flows.

Suitable for interaction with stakeholders/public etc

Rankings based on a simple low flow statistic would be easy to explain and it would be expected that most persons would appreciate the consequences of loss of large proportions of flow in dry times.

Suitability to water planning in Viet Nam

Not suitable for establishing comprehensive environmental flow rules for major storages or regulated rivers.

May be of some limited use in unregulated for impact ranking purposes or setting of flow levels at which pumping for low priority uses was restricted.

TEXAS CONCENSUS THREE ZONE CONCEPT

Where developed

Texas USA

Where applied

Texas USA

Description

hydrologic method

The planning criteria for the Texas State Water Plan set out default criteria and operational guidelines that are to be used in relation to new on river reservoirs. These are aimed at meeting environmental flow goals whilst protecting water supply and water quality during low flow conditions.

When storage levels are higher (above 80% full) the criteria specify that flow releases must be equal to the lesser of the median flow for the month or the inflow actually occurring. At lower storage levels the maximum flow that must be released decreases to the 25th percentile flow for the month and then to a n even low level in more extreme circumstances. Similar rules apply to diversions direct from the river. When flows exceed the median flow for the month, then diversion rates must be managed to ensure that at least the median monthly flow passes downstream. At lower flow levels the amount that must pass downstream decreases.

The numerical values prescribed by the guidelines are not intended to be used where more site specific information and data is available. The Plan also expects that for larger projects the actual numerical values will be determined by site specific studies.(Texas Parks and Wildlife Department 2003)

Information required to apply technique

A length of reliable recorded or constructed flow data which is of adequate length and reliability to allow assessments of natural flow monthly flow percentile values.

Monitoring of flow and water storage conditions to determine which rule that is applicable at any time.

Output produced

A set of flow rules that vary with water supply risk, time of year and current flow conditions

Strengths

The rules acknowledge the benefits to the environment that come from recognition and protection of natural flow variability and provision of flows and managing of volumes stored or taken from the river in a way that reflects the natural situation occurring at the time.

The rules also recognised that the marginal value of additional volumes of stored or diverted water changes with the volume of water currently in storage and the volume of water already being taken.

Weaknesses

The blanket application of set numerical rules such as these is will not produce optimal outcomes.

Requirements to adapt to Viet Nam

Determination of natural flow percentiles at each assessment point.

Suitable for interaction with stakeholders/public etc

The general rational behind rules of the general form of those set as defaults by this approach can be relatively easily explained to stakeholders

Suitability to water planning in Viet Nam

Not suitable for establishing comprehensive environmental flow rules for major storages or regulated rivers.

May be of some limited use in unregulated rivers for setting of flow levels at which pumping for low priority uses was restricted.

The concept that environmental flow rules can vary with the risk to maintenance of supply for essential human uses is one that could be applied to Viet Nam. Several water sharing plans for river basins in New South Wales in Australia also contain rules that vary environmental flow releases from dams with the level of water currently held in storage. Some of the New South Wales rules also relate required dam outflows to dam inflows occurring at the time and the volume of water that can be taken to the volume of flow in the river.

WETTED PERIMETER METHOD

Where developed

USA

Where applied

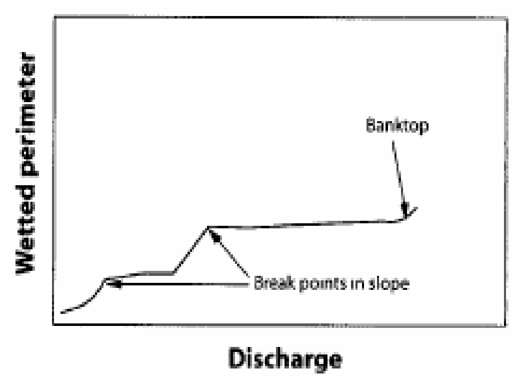
USA and

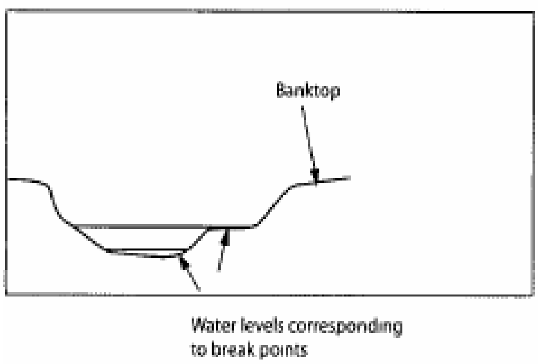
Description

hydraulic method - prescriptive

The assumption on which this method is based is that the well being of fish or other benthic fauna is a function of the area of habitat available to them and that this related to the wetted-perimeter a river, at those locations that exhibit the greatest habitat area sensitivity to flow reductions. For pool and riffle rivers this is the riffle. Riffles are also important wherever the prime environmental objectives are related to fish because they present a barrier to fish movement at low flow levels.

The relationship between the wetted perimeter and flow is established using cross sections of the river bed and hydraulic calculations or possibly direct measurements of flow. The point at which the increase in wetted perimeter with each unit of increase in flow declines rapidly (the break point) is and indicator of the point at which the complete bed of the river is wetted. This flow, or some proportion of, is taken to be the required environmental flow.





Generally reviewers recommend that the method should only be used in pool and riffle habitats (Armstrong et al 2003) and that the cross-sections be taken in straight reaches of the river on riffles which extend across the river and maintain hydraulic control over a range of flows. The method is said to work best in alluvial rivers, presumably because the cross section shape is less influenced by local geological variations. It is not suitable for use in rivers which have significant sections of unnatural or altered channel. This is because stream-flow requirements determined for natural riffle sites may not be sufficient to protect habitat at sites in a widened channel and may be excessive at sites in an artificially restricted channel; conversely, flow requirements estimated at sites with a narrowed channel may not provide sufficient flows for habitat protection in unaltered stream reaches.

Information required to apply technique

Representative cross sections plus any other information needed to carry out hydraulic calculations necessary to derive flow level versus flow height relationship.

Output produced

A single environmental flow value.

Strengths

No natural flow data is required to derive the flow recommendation.

Relatively low cost but some specialist expertise required to carry out hydraulic calculations.

Weakness

The approach is simplistic and really only relevant to determination of local critical flow levels relating to fish.

It is only applicable to pool and riffle alluvial systems, which are generally smaller rivers and not where the natural river form is unstable or has been significantly altered by gravel or sand mining.

It would be difficult to maintain consistency in selection of cross sections from location to location and accuracy and consistency in calculation of the flow versus height relationship.

Requirements to adapt to Viet Nam

No particular technical difficulties.

Suitable for interaction with stakeholders/public etc

Only in situations where there is general agreement that maintenance of fish movement is of critical importance.

Suitability to water planning in Viet Nam

Not suitable for establishing comprehensive environmental flow rules for major storages or regulated rivers.

This method may have some limited role in assessment of critical flow levels in pool and riffle systems, where maintenance of fish stock is seen to be of particular importance and movement is seen to be the key to their preservation.

R2 CROSS METHOD

Where developed

Colorado USA

Where applied

USA

Description

hydraulic method - prescriptive

The R2Cross method is based similar objectives and assumptions to those of the wetted perimeter approach, namely that maintenance of fish habitat and that this is achieved if flows at riffles are adequate. The R2 cross approach however applies 3 criteria to its assessment of adequacy, namely a minimum water depth, minimum percent of bankfull wetted perimeter and a maximum average velocity. The average depth and, to a lesser extent, the bankfull wetted percent are a function of the stream top width. The average velocity is a fixed value for all stream sizes.

The criteria are not varied with time of year, however the extent to which they are required to be met may be. For example in both Colorado and Massachusetts's applications the only 2 of the 3 criteria have to be met in the season of lowest flow.

The flow versus height relationship and the value applicable to depth, wetted perimeter and velocity at a given flow are calculated using Mannings, HEC or other standard hydraulic methods. Flow measurements and velocity, depth and wetted perimeter measurement could also be used to establish the relationship.

As with the wetted perimeter method, reviewers recommend that the method should only be used in pool and riffle habitats (Armstrong et al 2003) and that the cross-sections be taken in straight reaches of the river on riffles which extend across the river and maintain hydraulic control over a range of flows. The method is said to work best in alluvial rivers, presumably because the cross section shape is less influenced by local geological variations. It is not suitable for use in rivers which have significant sections of unnatural or altered channel. This is because streamflow requirements determined for natural riffle sites may not be sufficient to protect habitat at sites in a widened channel and may be excessive at sites in an artificially restricted channel; conversely, flow requirements estimated at sites with a narrowed channel may not provide sufficient flows for habitat protection in unaltered stream reaches

Information required to apply technique

Representative cross sections plus any other information needed to carry out hydraulic calculations necessary to derive flow level versus flow height relationship.

Output produced

A single environmental flow value.

Strengths

No natural flow data is required to derive the flow recommendation.

Relatively low cost but some specialist expertise and experience required to carry out hydraulic calculations.

Weakness

The approach is simplistic and really only relevant to determination of local critical flow levels relating to fish. The drop from satisfaction of all 3 criteria to 2 criteria in low seasons is arbitrary.

It is only applicable to pool and riffle alluvial systems, which are generally smaller rivers and not where the natural river form is unstable or has been significantly altered by gravel or sand mining.

It would be difficult to maintain consistency in selection of cross sections from location to location and accuracy and consistency in calculation of the flow versus height relationship.

Requirements to adapt to Viet Nam

The relationships between stream top width and other criteria and allowable stream velocity may not be appropriate for fish types in Viet Nam. Review by a fish ecologist would be required.

Suitable for interaction with stakeholders/public etc

Only in situations where there is general agreement that maintenance of fish movement is of critical importance.

Other comments

Suitability to water planning in Viet Nam

Not suitable for establishing comprehensive environmental flow rules for major storages or regulated rivers.

This method may have some limited role in assessment of critical flow levels in pool and riffle systems, where maintenance of fish stock is seen to be of particular importance and movement is seen to be the key to their preservation.

INSTREAM FLOW INCREMENTAL METHODOLOGY - IFIM

PHYSICAL HABITAT SIMULATION – PHABSIM,

RIVERINE HABITAT SIMULATION - RHABSIM

Where developed

USA

Where applied

Widely used particularly in USA also in Canada, Europe, Japan and Brazil.

Description

habitat simulation method – bottom up interactive

The Instream Flow Incremental Methodology (IFIM) was developed by the US Fish and Wildlife Service. IFIM relates changes in flow to changes in habitat availability. Physical data collected from selected sites in the study area are used by the Physical habitat Simulation Model (PHABSIM) to determine factors such as velocity, flow depth and substrata type covered at various flow levels. RHABSIM is a commercially available version of the method which includes additional analysis capabilities.

The methodology provides information about habitat available at different flow levels and under different flow regimes. It will not provide a flow regime recommendation, except in the unlikely circumstances that the only management object is to optimise conditions for a single species. Instead it can provide information about the change in the habitat area that would occur for individual species under different flow conditions. It therefore allows calculation of habitat area changes under different differing management rule and development circumstances, providing of course that flow regime data relevant to the management rules and development levels is available.

The process has generally been used in relation to fish species, but has also been used in relation to invertebrate species and for some broader ecosystem purposes (see Tharme 2003)

The decision about which development and management option is appropriate is still up to negotiation and consideration of socio-economic impacts and also variations in impacts on the various target species.

It is important to recognised that the process does not predict species abundance, only estimates of relative habitat availability.

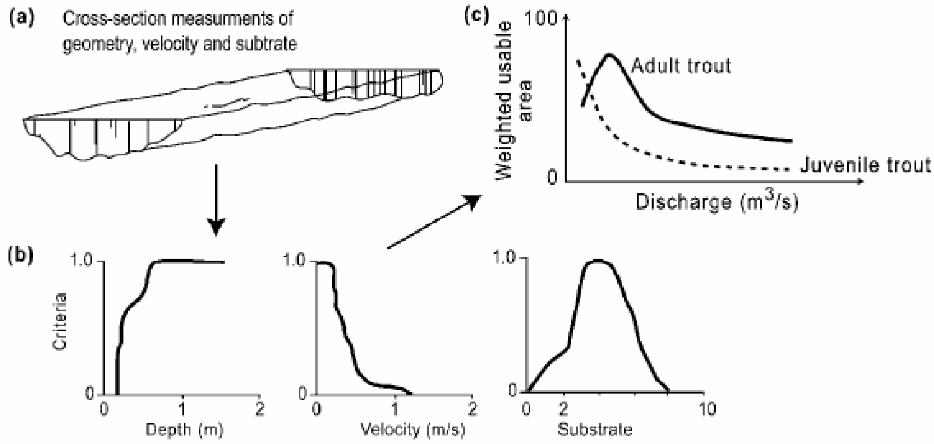
The process requires:

- selection of target species and development of habitat suitability relationships in relation to flow depth, velocity etc – these can be for different life stages of the species,
- identification of representative or critical river sections,
- selection of specific sites for which cross section and other data is to be collected,
- collection of field data,

- hydraulic and habitat modelling using PHABSIM and flow data describing current or expected flow regimes (note this will generally require hydrologic modelling) to produce Weighted Useable Area (WUA) data,
- interpretation of assessment results carried out for alternative management and development combinations,
- presentation of results in a form which is of value to the decision process and decision makers.

Suitability index curves, which describe the likelihood that particular species or life stages of a particular organism will be present for each assessed hydraulic or substrate condition, are essential to the calculation of WUA. These curves can be based on detailed field data concerning the presence of target species in the various habitat types under differing flow depth and velocity conditions. They can also be based on expert opinion if this exists.

The process of WUA calculation is illustrated in the following diagram (Gordon et al 2004)



Field data used to develop suitability index curves should only come from streams where there is little or no flow change, water quality decline or harvesting pressure influence on species presence. It is also important that the field data come from the target river or comparable systems. Where data is taken from other systems it is important that there be no differences in water quality or temperature which may influence species presence and behaviour.

PHABSIM software is free and available from a number of sources including:
http://www.mesc.usgs.gov/products/software/phabsim/phabsim.asp
RHABSIM is available via www.northcoast.com

Information required to apply technique

Ecological data or expert scientific advice that can be used to develop habitat suitability relationships.

Detailed cross section and habitat information from an adequate number of critical and representative sites in the target river.

Output produced

Change in habitat area with changes in the streamflow regime.

Strengths

No natural flow data is required to derive the flow recommendation (although it may be a necessary precursor to development of the flow regimes for various development and management conditions).

The methodology provides data that is more ecologically valid than simplistic single value "minimum flow" methods. The data it provides is also of much greater value as part of the environmental input to determining the optimal trade-off between economic, social and environmental outcomes.

Weaknesses

It is doubtful if there would be many rivers in Viet Nam where the effects of water quality change and harvesting of species has not affected species presence and abundance. It therefore may be difficult to develop reliable habitat suitability relationships for many species of interest to decision makers.

The information requirements involved in IFIM/PHABSIM are extensive and collection is time consuming. This combined with the lack of developed suitability indexes applicable to Viet Nam means that the costs and effort involved in applying the method would probably only be justifiable in connection with large scale, large impact projects.

Considerable expertise is required to apply the methodology.

Changes in water temperature, water quality, nutrient inputs etc that may also result from developments such as dams may render the suitability index relationships which a PHABSIM analysis has used invalid. Existing natural factors such as predator effects or lack of sufficient food may also mean that habitat area is not a reliable indicator of species presence or abundance. This may be because these factors rather than habitat area are limiting fish and other species numbers below the potential carrying capacity, and therefore numbers are insensitive to change in WUA.

One concern of relevance to Viet Nam and referenced in (Gordon et al 2004) is a finding that the relationship between fish biomass and WUA was better in coldwater steams than in warmer streams(Gore et al 1988). It was suggested this was because coldwater streams had simpler ecosystems and more predictable hydrologic regimes.

It has also been suggested (Oliver 1994) that the inherent variability between habitats within a stream reach, render IFIM procedures invalid for whole streams and even whole reaches.

The methodology does not address any of the flow variability factors affecting reproduction, migration etc behaviours of target species or the variability needed to maintain ecosystems.

It does not address geomorphic issues, such as sediment transport etc,

Requirements to adapt to Viet Nam

Development of habitat suitability relationships.

Suitable for interaction with stakeholders/public etc

Provides a better basis for discussion and decision making than simple "take it or leave it" minimum flow recommendations.

Suitability to water planning in Viet Nam

High cost and data needs mean this method is not suitable for broad scale water planning purposes.

Not suitable for analysis of development impacts in the absence of reliable habitat suitability relationships.

Other weaknesses (see above) also mitigate against use of this and other habitat suitability methodologies for any purpose in Viet Nam.

BENCHMARKING

Where developed

Australia

Where applied

Queensland Australia

Description

holistic top-down approach – may be used prescriptively or interactively

The approach provides an assessment of the 'risk' of environmental harm or likely scale of change or a recommendation regarding the range of change that should be permitted.

The study river's current or projected flow regime is described in terms of a set of relevant flow indicators/statistics, each of which is subsequently used to develop benchmarking models linking flow regime change with ecological and geomorphic responses. Information on alterations of natural flow regimes in the subject basin, or from other comparable river systems, is linked with observed ecological and geomorphic impacts. This may be done using existing assessments, observations of experts or by evaluations conducted as part of the assessment process. The approach uses a Technical Advisory panel (TAP) which operates as an expert panel (see later entry in this appendix) and provides advice using the developed relationships between hydrologic change and ecological and geomorphic impacts.

The models are then used to develop a risk assessment framework for evaluation of potential environmental impacts of future WRM scenarios.

Information required to apply technique

A number of sites with a similar natural hydrology, geomorphology and ecology to the portion of river under assessment must exist within the river system or in other comparable river systems.

These sites must be subject to a range of infrastructure development and water extractions which reflects the possible range in the river system being assessed.

Information regarding the hydrologic, ecologic and geomorphic conditions should be available for the benchmark sites so that reliable relationships between changes in flow statistics and the risk or degree of impacts can be developed.

Output produced

Assessments of the impacts likely to result from alteration of the natural flow regime or assessments of the benefits likely to result from flow changes that move the flow regime back toward the natural.

Strengths

The approach can provide advice about a range of possible ecological changes. The method does not require detailed or long-term ecological monitoring at the assessment site.

It allows a range of possible flow management outcomes to be assessed.

Weaknesses

Benchmarking may be affected by 'confounding factors'. These may mean that the assessed state of chosen benchmark sites is not a reliable guide to the future state of the site or river under assessment. These factors could include time lags between hydrologic impacts and the appearance of ecologic or geomorphic changes at benchmark sites. It could also include water quality, land use and fishing pressures differences.

Requirements to adapt to Viet Nam

A set of hydrologic statistics suitable for use in benchmark analysis would need to be developed.

Suitable for Interaction with public

The principle behind the process is easy to understand and is easy to explain to decision makers and to others with an interest in the decisions that are being made.

Suitability to water planning in Viet Nam

Lack of sufficient long-term ecologic data and the existence of many 'confounding factors' limits the usefulness of this approach in Viet Nam.

Further local expert assessment may however be worthwhile to determine whether there is sufficient data for a range of development levels in some river types to allow the approach to be of value. One possible example may be the short unregulated coastal river systems of central Vietnam.

EXPERT PANEL ASSESSMENT

SCIENTIFIC PANEL ASSESSMENT

Where developed

Australia

Where applied

Australia

Description

approach – may be bottom up or top down, may be used prescriptively or interactively
Experts from a range of disciplines are engaged to make environmental flow recommendations or assess the benefits or effects of flow management options. The individuals can come from any relevant scientific discipline but should include both geomorphic and ecological experts.

If the panel has been engaged to make flow recommendations, it is important that they be provided with good advice regarding the river management practicalities. It is also important that good hydrologic advice be available, preferably in the form of statistical assessments relevant to each of their disciplines.

The individual panel members are generally permitted to choose the type of analysis, relevant to their area of expertise, which they undertake. The process may involve field inspections and assessments, if time and finances permit or it may be carried out as a desktop process. It may also include meetings between the Panel and outside experts or stakeholders.

The Panel then discusses and debates the opinions of panel members until a consensus is reached regarding the assessment of flow management options or environmental flow recommendations.

It is important that Panels be permitted to provide objective scientific advice and that they are not required to make tradeoffs between environmental and social or economic outcomes. The Panel members must also act as scientific experts and must not be to be required or allowed to become advocates for particular organisations or interest groups (Cottingham et al 2001).

Information required to apply technique

Where Panels are being asked to develop environmental flow recommendations it is essential that there be a clear definition of the environmental and river health outcomes that are being sought.

The expertise of the Panel must match the issues or questions it is being asked to address. The more general the questions and broader the issues the greater the range of expertise required.

Panels require hydrologic, hydraulic, geomorphic and ecological information and data relevant to the analysis they need to carry out to make recommendations.

Output produced

This can range from specific recommendations about flow regimes to assessments of the impact of alternative management options.

Strengths

The process allows consideration of a wide range of ecological impact areas to be considered, for their interactions to be considered and for an integrated set of assessments or recommendations to be developed. It allows individual experts to choose the assessment methodology which best suits their scientific discipline and the data which is available or can be made available within the permitted timeframe.

Weaknesses

The expertise and personalities of individuals who make up a Panel will affect the advice it provides. Because of this two Panels may produce quite different recommendations (see Bishop 1996) with biases that reflect the expertise of the participants or the dominance of individual personalities on the Panels.

Lack of adequate data will affect the reliability of Panel advice.

Reliable assessments may take time to complete (6 to 12 months in Australia) , in part because of the practical problems involved in gathering the required experts together but also because of the time needed to gather data and for individual experts to carry out analysis prior to or subsequent to Panel meetings.

Requirements to adapt to Viet Nam

Panel processes which are sensitive to local social or other circumstances would need to be devised.

Improvement of data and information exchange between agencies would assist expert panel processes.

Hydrologic modelling and assessment capabilities would need to be improved.

Suitable for interaction with stakeholders/public etc

Panel members may be willing to explain their recommendations to decision makers and stakeholders; however it is important that such interactions not be permitted to become forums in which Panel members are pressured into adjusting recommendations.

Other comments

The Building Block Methodology and Downstream Response to Imposed Flow Transformations approaches also use expert panels.

Suitability to water planning in Viet Nam

The process places high demands on data and on the availability of experts who are willing to provide opinions for which there might not always be clear supporting evidence.

However expert panel processes, do provide a means by which the knowledge that is available can be brought together and synthesised in a reasonably efficient manner to provide flow recommendations.

BUILDING BLOCK METHODOLOGY (BBM)

Where developed

South Africa

Where applied

South Africa and Australia

Description

holistic approach – bottom up- prescriptive (although multiple use can assist interactive discussions)

This is a structured process for development of a flow designed to meet a predetermined outcome.

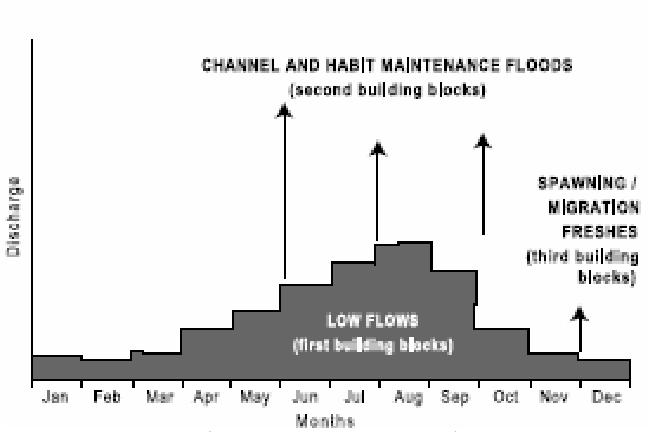
The presumptions upon which BBM is based (Arthington 1998b) are:

- plants and animals associated with a river can cope with low flow conditions that occur naturally often occur
- plants and animals may require higher flow conditions that occur at certain times
- if the most important characteristics of natural low flows and high flows are incorporated into a modified flow regime this will assist in maintaining these plants and animals and natural river processes, and
- certain flows influence channel geomorphology and there inclusion will aid maintenance of natural channel structure and therefore maintenance of the natural diversity of habitats.

The initial phase of the process involves a planning meeting, followed by gathering of hydrologic, hydraulic, ecological and other relevant field data. This is used to produce an initial "Starter Document". The starter document provides background information for the experts who will participate in subsequent phases of the process as well as providing a background document which can serve as a reference at future times.

The second phase involves a major workshop. This is attended by water managers and engineers involved in design and management determinations as well as scientific experts from relevant disciplines (ecology, geomorphology etc). The workshop then builds a recommended flow regime designed to meet a desired future long-term river condition.

Flow regime decisions are made for reach month. The flow regime is built up from a monthly base flow plus special purpose higher shorter period flows (see diagram below taken from Gordon et al 2004). Proponents of particular levels or frequencies of flow are required to state their reasons. The workshop then discusses the proposals until a consensus recommended flow regime is reached.



Building blocks of the BBM approach (Tharme and King 1998)

The third phase requires the linking of the environmental flow recommendations to the development and water management decisions being made in relation to the river system. This involves comparison of projected flow outcomes for different development or management options with the flow recommendations that have been made.

Information required to apply technique

Hydrologic, hydraulic and ecological information is required. Experts able to cover the required range of disciplines must also be available.

Output produced

A flow regime that is assessed to be capable of achieving a desired river health outcome. If several outcomes are nominated then several flow regime recommendations can be provided.

Strengths

The method provides an efficient and structured way of converting ecological understandings into flow regime recommendations.

The clear documentation of the process each time it is applied which can then assist in achieving more consistent results, improving the process and dissemination of information relevant to local flow management and development.

Experience gained in application of the process in South Africa has identified a variety of ecological knowledge gaps. This has lead to a range of medium to long-term projects designed to improve the methodology.

This may in fact be a side benefit of this process, and also the DRIFT process, in that it helps identify critical information and data gaps and focus research on issues of immediate concern and value to management decisions.

Weaknesses

It is very difficult to define a desired future state of the system in a way which is objective and has the same meaning to all workshop participants. There is also a temptation when describing an environmental outcome to aim unrealistically high.

The success of the approach (and all others that require expert panel input) also depends on the availability of experts with a good understanding of the plants, animals and processes occurring in the river system. It is unlikely that these will be readily available in most areas of Viet Nam.

Variations in the range of information and data available to experts in different disc and dominance by individual participants in the workshop processes may bias conclusions.

Requirements to adapt to Viet Nam

Panel processes which are sensitive to local social or other circumstances would need to be devised.

Improvement of data and information exchange between agencies would assist expert panel processes.

Hydrologic modelling and assessment capabilities would need to be improved.

Suitable for interaction with stakeholders/public etc

The process provides a good deal of information that could be of value in public discussion of flow management proposals and for discussions with decision makers.

Suitability to water planning in Viet Nam

The process places high demands on data and on the availability of experts who are willing to provide opinions for which there might not always be clear supporting evidence. However this approach, like other expert panel processes, does provide a means by which the knowledge that is available can be brought together and synthesised in an efficient manner to provide flow recommendations.

However, the third phase in the process is cumbersome and it is not really suitable for use in assessments involving a range of possible options is limited.

Its dependence on a clearly definition of desired outcome prior to commencement of assessments would also often limit its usefulness.

FLOW RESTORATION METHODOLOGY

Where developed

Queensland, Australia

Where applied

Australia

Description

framework – top down - interactive

The Flow Restoration Methodology designed to analyse how an existing regulated flow regime could be modified to restore some of the natural characteristics of a river (Arthington 1998b). It involves an assessment of the current impacts of flow regulation and preparation of a report. A workshop process is then used to identify possible environmental flow options and likely benefits. These are then computer modelled and the implications for yield of the system assessed. The results are reviewed, along with assessment of any required infrastructure changes or complementary management actions.

The approach is similar to that undertaken in the Australian state of New South Wales as part of the process for design of environmental release rules for existing major dams throughout the state. The process used in New South Wales was however not as structured or exhaustive as that applied in the Queensland case.

Information required to apply technique

Information on the current state of health of the river and its associated ecosystems.

Hydrologic information on the impacts of river regulation on the flow regime and the low regime consequences of proposed management rule changes.

An understanding of the relationship between changes inflows and the consequences for various ecosystems.

Output produced

Information on possible river health benefits and impacts on the yield and reliability of the dam and supply system.

Strengths

The approach illustrates how holistic approaches can be used to assess options for adjusting operation of dams and water supply deliveries to improve environmental outcomes downstream.

See “Expert Panel Assessment” for further possible strengths.

Weaknesses

The success of the approach (and all others that require expert panel input) depends on the availability of experts with a good understanding of the plants, animals and processes occurring in the river system. It is unlikely that these will be readily available in most areas of Viet Nam.

See "Expert Panel Assessment" for further possible weaknesses.

Requirements to adapt to Viet Nam

See "Expert Panel Assessment"

Improvement of data and information exchange between agencies would greatly assist the process.

Hydrologic modelling and assessment capabilities would need to be improved.

Data and research to support the development of basic understandings regarding the links between flow change and river health outcomes.

Suitable for interaction with decision makers/ stakeholders/public etc

The processes used in Queensland and New South Wales provide information regarding expected river health and system yield impacts that are useful in discussions with stakeholders. The yield impacts can also be used in determinations of the economic consequences of alternative management changes.

Suitability to water planning in Viet Nam

The analysis involved is not as structured as that which occurs under DRIFT and therefore outcomes may not be consistent, it also does not include any assessment of social impacts and relies on subsequent assessments to turn changes in yield into economic outcomes. However the detailed and highly structured DRIFT approach is probably not efficient for assessment of flow restoration alternatives. This is because the range of possible alternatives is often limited by infrastructure considerations or the acceptable level of impact on system yield.

DOWNSTREAM RESPONSE TO IMPOSED FLOW TRANSFORMATION - DRIFT

Where developed

South Africa

Where applied

South Africa

Description

framework – top down - interactive

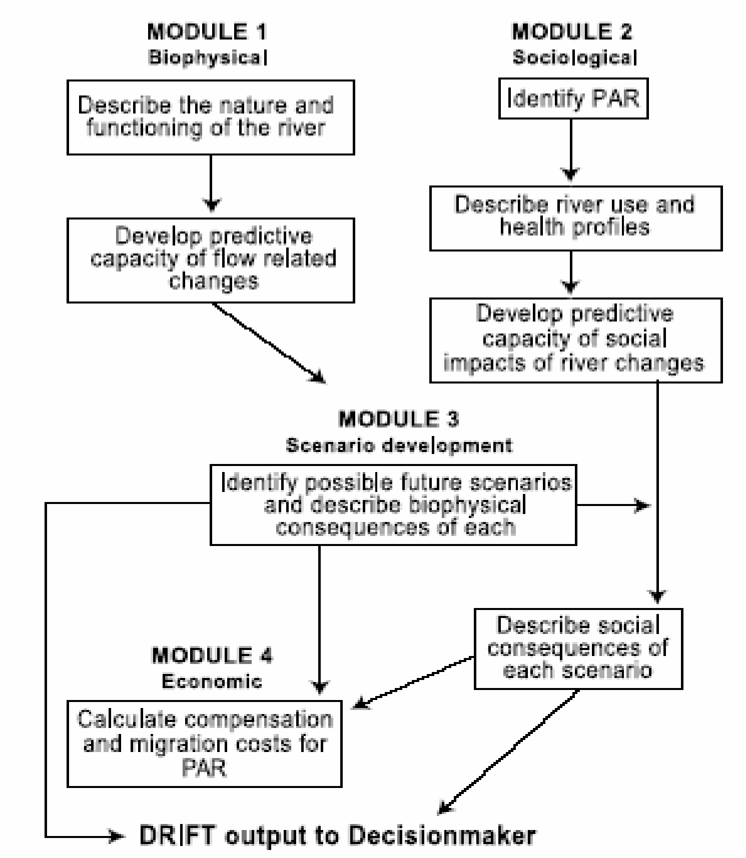
The assumption upon which DRIFT is built (Brown and King 2000) is that different features of the flow regime produce different ecologic and geomorphic reactions and therefore a decrease (or increase) in that one feature will produce different outcomes than a change in some other feature.

DRIFT is a very structured process by which:

1. the natural (or existing) flow regime is analysed to provide a set of standard flow statistics which cover low flows and high flows/floods, the time of year in which they occur and for floods the number, volume and duration of events in each size class,
2. these statistics are then linked to cross-sections of the river at a number of representative sites,
3. a standard set of reductions (or increases) in each flow statistic is then assumed and the ecologic, geomorphic and water quality impact of each these is determined and entered into a database,
4. the hydrologic statistics that would result from possible development or management scenarios are then calculated and the differences between these and the natural (or current) flow regime assessed,
5. the results of step 3 are then combined with the ecological, geomorphic and water quality impacts predicted under step 3 to provide a projected future river condition,
6. this is then used to identify the likely social impacts of each scenario on Persons at Risk (PAR) and a compensation or mitigation cost is calculated,,
7. the water or electricity yield that can be produced is also calculated, and
8. the river condition, social impact and water and/or electricity production outcomes are then fed into the forum or arms of government responsible for making management or development decisions.

The DRIFT process generally requires at least 2 workshops, one to deal with the bio-physical issues and the other to resolve socio-economic issues. However, these workshops do not require consensus agreements to be reached as the process allows for uncertainties regarding impacts to be included in process outputs.

The diagram below (taken from Gordon et al 2004) shows how the DRIFT activities interact:



Information required to apply technique

Reliable and reasonably long term flow data (20 years plus) is required to provide a complete set of hydrologic statistics.

Hydraulic information (cross-sections etc) must be collected from representative sites.

Available ecological information must be gathered and any deficiencies that can be filled in by gathering of data prior to determination of

Output produced

Projected river condition, economic and social impacts of possible development and/or management scenarios.

An impacts database which can then be subsequently used to assess the impacts of alternative scenarios.

Strengths

The DRIFT method has all of the strengths of the BBM approach, namely:

- it is an efficient and structured relating flow regime change to ecological impact,
- there is clear documentation of the process each time it is applied which can then assist in achieving more consistent results, improving the process and dissemination of information relevant to local flow management and development decisions,
- it will help to identify critical information and data gaps and focus research on issues of immediate concern and value to management decisions

Because it is a top-down process it doesn't depend on clear and specific definition of desired outcomes (often an impossible task and a weakness of BBM). This makes it a useful in circumstances where the question is how to optimise outcomes resulting from a possible range of alternatives.

The framework explicitly incorporates assessment and quantification of impacts on those who depend on the river for provision of household services such as water supply, food sources etc, a very important consideration in Viet Nam.

Once the DRIFT relationships between flow regime change and consequences are developed, the consequences of any number of future flow regimes arising from potential management or development scenarios can be assessed quickly and in a consistent fashion without a requirement to reconvene experts or conduct new studies. Because of this, the process facilitates resolution of questions such as how to get the best river health and socio-economic benefits for a given tolerable change in water yield or hydro-electric production which often requires assessments of a large number of possible management options.

It allows prediction uncertainties to be recognised and incorporated into the information provided to decision makers.

Weaknesses

The success of the approach depends on the availability of experts with a good understanding of the plants, animals and processes occurring in the river system and the availability of suitable data.

Variations in the range of information and data available to experts in different disc and dominance by individual participants in the workshop processes may bias conclusions.

It is relatively time consuming and requires a wide range of data

Requirements to adapt to Viet Nam

Workshop processes which are sensitive to local social or other circumstances would need to be devised, however, as there is no requirement for consensus this should not be the issue it is in more usual expert panel processes.

Improvement of data and information exchange between agencies would greatly assist the process.

Hydrologic modelling and assessment capabilities would need to be improved.

Data and research to support the development of basic understandings regarding the links between flow change and river health outcomes.

Suitable for interaction with decision makers/ stakeholders/public etc

The process provides detailed impact projections and brings river health, social impact and economic assessments together in a single package that should be useful for discussions with all parties.

Suitability to water planning in Viet Nam

For the reasons outlined under "Strengths the DRIFT framework and processes would be very suitable for adoption in relation to major development and management decisions, particularly those where there are several possible options.

This approach, and other Holistic approaches, should not be seen as substitutes for the gathering of good ecological information and other data, rather they should be viewed as a means of making the best use of what is available. It is important that action be taken to deal with information or data deficiencies identified in the process of applying DRIFT, or any other holistic approach so that future applications of such approaches have a better knowledge foundation.

Appendix 3 – Comparison of results of "minimum flow" methods based on data in Armstrong et al 2004

Location	Wetted perimeter		R2Cross 3 of 3			R2Cross 2 of 3			Tennant Method					
									50% maf excellent		30% maf "fair"		10% maf "poor"	
	flow l/sec/km2	nat flow %ile	flow l/sec/km2	nat flow %ile	as % of wetted perimeter	flow l/sec/km2	nat flow %ile	as % of wetted perimeter	flow l/sec/km2	as % of wetted perimeter	flow l/sec/km2	as % of wetted perimeter	flow l/sec/km2	as % of wetted perimeter
Squannacook R, MA	3.8	79	5.9	68	154%	3.0	86	77%	9.7	254%	5.8	151%	2.0	51%
Beaver Brook, NH	1.4	88	4.3	74	300%	2.2	85	154%	8.7	615%	5.0	354%	1.7	123%
Old Swamp River, MA	5.2	75	18.6	34	354%	3.2	84	60%	11.1	213%	6.7	127%	2.2	42%
Wood River, RI	3.6	95	8.0	77	221%	5.4	87	148%	11.9	330%	7.1	197%	2.4	67%
Mt Hope R, CT	5.2	70	6.8	65	129%	3.8	76	73%	9.9	190%	6.0	115%	2.0	38%
Little River, CT	4.4	82	10.5	57	240%	4.0	85	93%	10.4	238%	6.2	143%	2.1	48%
South River, MA	3.1	92	10.1	60	329%	7.9	68	257%	11.9	389%	7.1	232%	2.4	79%
Green R, Colrain, MA	6.3	72	23.0	29	362%	9.3	62	147%	11.9	188%	7.1	112%	2.4	38%
Sevenmile River, MA	4.3	75	4.3	74	100%	1.7	88	41%	9.5	223%	5.7	133%	1.9	44%
Green R– Will'town, MA	3.5	86	9.2	62	263%	4.6	61	131%	10.5	300%	6.3	181%	2.1	59%
Median	4.0	81	8.6	64	251%	3.9	85	112%	10.4	246%	6.3	147%	2.1	49%
Average	4.1	81	10.0	60	245%	4.5	78	1.2	10.6	294%	6.3	175%	2.1	59%

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